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**ELECTRONIC COMPUTERS and
MANAGEMENT CONTROL**



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ELECTRONIC COMPUTERS and MANAGEMENT CONTROL

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ELECTRONIC COMPUTERS AND MANAGEMENT CONTROL

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Preface

This book is written primarily for the business executive. Our purpose is to explain certain new developments which may have a greater influence on the management of enterprise than any other single group of events have had since the first industrial revolution.

These developments include electronic computers and other new equipment for recording, processing, and communicating information. Of equal importance, though not as well publicized, are new methods for scientific analysis of business data.

Together these developments are making possible automation of the office and of the factory.

The book does not require that the reader have technical training. Therefore it should be helpful to anyone who is interested in coming changes in business and society. Automation will have a major impact on our way of life. To understand why, it is necessary to have some knowledge of the way electronic computers operate and of the scientific approach to management problems.

The book describes the fundamental characteristics of electronic systems and the basic concepts of the scientific methods of analysis. It shows how they will influence management planning and control. It describes dozens of actual applications and gives briefer references to many more. For readers interested in further details, the appendixes and the selected bibliography provide additional sources of information.

During the three years that this book was in preparation, the authors have been aided by so many people that it is impossible to list them all. Each of the many references to actual experiences or to particular equipment means that someone (often a group) has helped us. In particular, however, we should like to thank W. W. Cooper of Carnegie Institute of Technology, Richard Canning of Canning, Sisson Associates and of the Management Science Project at UCLA, Irving

Lieberman and Jack Thorne of Litton Industries, Erwin Tomash of Sperry Rand, and Don Wall of International Business Machines.

Perhaps the greatest contribution has been the patience of our wives and children for three long years of lost week ends, evenings, and holidays.

George Kozmetsky

Paul Kircher

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CHAPTER ONE

Introduction: Why Be Interested in Computers?

The development of the electronic computer has created new opportunities for management planning and control. Automatic handling of information can become more rapid, more efficient, and often less costly than ever before.

As our economy has become more complex, and as corporations have grown in size, in variety of product, and in extent of market, the need for improved systems of planning and control, and data processing, has become increasingly evident. Executives have recognized this need. They have purchased or leased office machines, analyzed procedures, and encouraged attempts to raise clerical efficiency. They have studied reporting systems. They have attempted to relate the gathering and processing of information to the decision needs of the organization.

Nevertheless, the information-gathering and communication process has remained among the less efficient and most unsatisfactory of business functions. This situation has led executives to a consideration of the possible use of new inventions and developments in the field of electronic processing of information.

An electronic system can:

1. Increase transmission, processing, and reproduction speeds.
2. Reduce the need for manpower.
3. Reduce storage-space requirements.
4. Automatically handle intermediate steps in data processing, thus giving more flexibility in preparation of a variety of reports, while at the same time increasing accuracy.

Reduction of clerical cost has been a major factor in favor of using electronic systems. As it has become increasingly evident that a

computer can pay for itself, more and more companies have placed orders for computers or have initiated studies leading to expected installations.

However, recent experience has shown that the major impact of these new systems will come in a field of even more significance than reduction of clerical cost. The proper use of electronic systems, together with application of new methods of analysis, can revolutionize management planning and control.

Improvements in the system for planning and control will:

1. Provide more useful information concerning operations, for use in making better decisions.
2. Enable management to relate the procurement, production, and sales programs for each division in a way that results in the largest profits for the company as a whole.
3. Help management to make the best allocation of financial and other resources.
4. Eliminate certain management functions and strengthen others.

A few of the first companies to link several plants were U.S. Steel, du Pont, General Electric, Standard Oil of New Jersey, and SKF Industries. Special groups are assigned to the study of the potential benefits of the new developments. Electronic systems are installed to link various plants to central computers.

Don Mitchell, chairman of the board of Sylvania Electric, announced that his company's reason for building a data-processing and communication center was to serve an integrated area and not any single plant. He also said that cost savings were not the consideration. His competitors had only two years within which to match his anticipated system for providing management with complete daily information.

Scientific Developments. Electronic computers are only one of a number of scientific developments of immediate concern to the executive. Among these developments are new methods of recording information, of storing it, and of printing it. In addition, a series of inventions have appeared which are summed up in the term "automation." * Since so much information originates in the factory, and

* The word "automation" is believed to have been used first by D. S. Harder, Ford Company vice-president, to describe a system for automatic handling of parts between progressive stages in production. About the same time, John Diebold also used the word to mean both automatic handling and the process of making things automatically. The latter usage has become more general.

since electronics is of direct importance in factory automation, it is expected that computers eventually will be used for controlling production processes as well as for handling clerical information.

In both office and factory, and for certain types of engineering and other research as well, there also has been a development of certain new scientific methods of analysis. These methods use tools which are primarily mathematical in nature, although not necessarily so. One of the names given to this development is "operation research." Since the new concepts emphasize the application of scientific methods to business problems, a somewhat broader name also given to this new field is "the management sciences." In any case, these new concepts are of direct concern to the businessman.

Need for Timely Executive Attention. There are a number of reasons why decisions concerning the use of the new equipment and the new methods will have to be made by top executives, and soon. The attempt to apply scientific methods to the problems of general management has frequently been made before, but with little success. Failure came for a number of reasons, but a major factor was the lack of equipment for rapidly gathering and processing data and the lack of scientific tools with which to attack business problems. Now, the equipment is available, many of the required scientific tools are available, and more are being developed.

In order to compete effectively in the future, a company may have to make extensive use of the new equipment and new analysis methods. This may require an extensive reconstruction of its system of management planning and control, substantial revisions of all data-handling processes, and perhaps a realignment of the organization structure. It may, for example, mean that a company should reverse a present trend toward decentralization because control data can be assembled and analyzed in a central office, from across the country, as easily and as quickly as they now are sent to an office across the street from the factory. Instructions can be returned as easily and quickly. The additional expense for communication may well be insignificant compared with savings.

On the other hand, the tools may be used to further decentralization of decision making. Distant managers now can be provided with full information.

A new approach to the decision-making process itself may become necessary. Teams of specialists may make scientific analyses of data

and report to management in ways that will be considerably different from and more effective than those employed at present.

Top-management Considerations. If for no other reason, these developments will command top attention because of their cost. Electronic computers are expensive at present, although they will become less costly as time goes by. Automation, system studies, training of personnel, etc., will add substantially to the cost.

Moreover, personnel problems will be acute. Large numbers of factory and clerical workers can be displaced. Workers with special skills for machine maintenance, systems study, and advanced data analysis must be retrained or hired.

Decisions will have to be made as to whether the machines and methods should be introduced gradually, in a sort of evolutionary process, or whether the whole matter is so revolutionary that no halfway approach will do. Further decisions concern the type of equipment. A rather surprising number of new manufacturing firms are entering the field. Executives will have to choose from several suppliers and may find it best to assemble a unit from components produced by several different firms.

Similarly, advanced methods of data analysis are not immediately adaptable to most business problems. Careful examination of specific situations must be made before the methods can be used.

Management has the responsibility to administer this transition with the least harmful impact on society. At the same time managers have an important role to play in securing the full advantages of the new developments for their own companies. They have to evaluate wholly new concepts of doing business. While they will not have to understand all the details of new tools and methods, they will be responsible for decisions as to where and when these are to be used.

Computers and automation will require long-term commitments of capital. Since these investments can be justified only if they contribute to earnings over an extended period, a forecast of such contributions must be made. Frequently this estimate can be little more than an intelligent guess, in view of all the factors which bear on the decision.

This problem leads to a consideration of the environment as a whole, the framework within which the company must try to operate. Businessmen have become increasingly aware that their results are

influenced to a major degree by factors over which they have little or no control. One of these is the result being achieved by all other units in the economy.

Another major factor, in a sense controlled and yet almost equally difficult to predict, is governmental action. Through its regulations, spending, borrowing, financial controls, psychological impacts, etc., government has a tremendous influence on business.

The evaluation of these factors is obviously a difficult task. Fortunately, many of the same analysis methods which are being proposed and used for other aspects of the business are of direct use in studying these problems.

Need for Technical Understanding by Management. Executives cannot achieve their goals of meeting competition and of serving the many interests in the business and society unless they are alert to new developments which will enable them to administer their business more effectively. But though this is admitted, it does not follow that developments in electronic computers, scientific management, and automation are the best answer to their specific problems. The new machines and methods offer no panacea. For many companies they probably will not offer much assistance, at least within the immediate future.

What can the individual executive do?

He can study these developments sufficiently so that he will be able to assess their significance to his particular business. This is a responsibility that he cannot delegate. He can learn in general what the machines will do, how the methods of data analysis operate, what automation means—not in great detail, but sufficiently so that he can assess recommendations as to when and where they can be put into use in his business.

Does this mean the administrator with technical training will have an advantage?

It does, for even to communicate effectively with the experts in these new fields a certain degree of technical understanding is required.

Should tomorrow's administrators be chosen solely from men with technical training?

Not necessarily. For years, as technically trained men have moved into executive positions, they have tried to bring their past skills to bear on the administrative problems of their companies. As a rule, however, they found that administrative problems were more com-

plex than they expected. Therefore, like the nontechnical administrators, they have had to rely also on personal experience and the "art" of management. This will continue to be so.

Summary. The executive need not become an expert in electronics or mathematics. As with other technical areas of business, an executive can learn to deal with the problems involved by acquainting himself with general aspects—with capabilities and limitations of the systems and methods. For the details, he can rely on experts. His task is to select the experts and to administer their efforts so as to produce maximum benefits for his company, his customers, his employees, and society.

The purpose of this book is to assist the executive by describing the major characteristics of electronic systems and new methods of analysis as these are related to management planning and control. The book attempts to provide the background required in order that the executive may obtain the economic benefits offered by these new developments.

CHAPTER TWO

What Is an Electronic Computer?

The use of electronic computers for business purposes is a development of the 1950s. Before this decade a few computers existed, but they were used solely for scientific computations. Since 1950, however, the growth of interest in electronics among businessmen has been remarkable. Articles in popular magazines have heralded the new "electronic brains." Professional journals, and meetings of professional societies, have discussed the potential of this new equipment. Orders for hundreds of computers of all sizes have been placed by businessmen.

A variety of claims have been made—that these new devices will handle all the data processing of a large business at a great reduction in cost; that they can read print, make computations, prepare statements and payroll checks, and so on. Sometimes statements are heard that the new systems will replace management itself.

What are these electronic computers? How do they work? Who is using them? How are they being used? In what ways does the business operation change when they are introduced?

Businessmen have found it difficult to get a simple answer to these questions. The electronic computers they have examined, and the ones which have been described as soon to be available in the future, differ so much in abilities, costs, and other characteristics that the machines hardly seem to belong to the same family.

Like the blind men describing the elephant, it is easier for the experts to talk in terms of the parts of the machines rather than of the whole. They speak of input devices, storage, logical elements, etc. These technical aspects seldom have a direct significance for the executive.

Electronic computers use electrical charges or magnetic marks to

represent business information, to compute with it, to store the data, and to drive a printer which produces numerical or alphabetical characters in familiar forms on reports. However, when one looks to see how the electrical charges are activated, he finds that they may come from data-processing devices currently employed, like punched cards. Or they may originate from some new form, like magnetic tapes. Some of the data may be taken from keyboards that have numerical or alphabetical keys, just as those currently used for ordinary typewriters or adding machines.

Furthermore, many of the operations of an electronic computer are not strictly "computation." The machines are also used to rearrange data, or to do logical processing, e.g., to select cost variances which are more than a certain range off standard, and to print out a report for special attention by management.

A major reason why it is so difficult to define "electronic computers" is the fact that the field is in a stage of transition. There is no single type of machine, or even a single type of process, which dominates the field. It is necessary to speak of electronic computers, particularly of those used for handling business data, in terms of "electronic systems." By electronic systems is meant a combination of various devices, rather than a specific machine or method.

General-purpose Computers. Electronic systems can be classified into two general types: general-purpose computers and special-purpose machines.

General-purpose computers, as their name implies, are electronic machines that do all types of arithmetical computations—add, subtract, multiply, divide, square root. In addition, general-purpose computers are capable of performing a large number of other operations. They can store data, compare items, prepare reports, and so on. As a result, they are very versatile. For example, they can do the payroll, handle accounts receivable and billings, do cost accounting, production scheduling, and budgeting.

A general-purpose computer can be regarded as a data-processing center, one that is completely integrated and able to perform all of the various functions of data processing: receiving information, converting information, storing data, sorting data, collating data, computing data, transmitting data, and putting the data into a usable form, as readable printed output.

A general-purpose computer, from a machine point of view, is a

combination of devices. These devices are linked in a way which permits the machine to perform operations by manipulation and transmission of electrical charges or magnetic marks. From the functional point of view, a general-purpose computer is a system which permits the user to process data for a large number of purposes, all within a centralized grouping of devices, which are primarily electrical in nature.

General-purpose computers can be further classified according to size and to the speed of computation. General-purpose computers may be either "large-scale" or "medium-sized." Computers which can handle a variety of problems and are extremely fast in arithmetical computation are generally referred to as large-scale general-purpose computers. Their rentals range from \$15,000 to \$50,000 a month. Computers which are smaller in size and slower in computational speed, but still able to handle a variety of problems, are referred to as medium-sized general-purpose computers. They usually rent at \$2,000 to \$6,000 a month. As yet there are no "small-size" general-purpose machines that sell for \$1,000 to \$25,000, although design engineers are nearing this goal.

Special-purpose Computers. Special-purpose electronic computers are limited either as to the type of computations they can make or as to the functions they can perform. For example, a special-purpose computer can be devised which only adds and subtracts. A machine designed to handle only customer billings, such as Bell Telephone's new automatic billing machine, can be termed a special-purpose computer.

In contrast to the general-purpose computer, the special-purpose computer is designed to handle separate aspects of data handling. A special-purpose computer might handle the recording of the number of calls but might not be able to compute the monthly telephone bill. The addition of more devices may enable the system to compute the monthly bill but still not handle payroll.

If the system were redesigned, however, so that the central computer could also make payroll computations, it might then be a general-purpose computer. Yet much of the "billing-special" system still might be retained. The same input system, for example, might be used.

Special-purpose computers also can be classified by their size, large or medium, and by their speed.

The limited variety of functions which it can perform, both mathe-

mathematical computations and business data-processing functions, makes a machine special-purpose; but for certain operations the special computer may outperform a large-scale general-purpose computer.

MISCONCEPTIONS

As a result of the publicity given to electronics in recent years, many people seem to believe that computers are actually electronic brains. Electronic computers are indeed marvelous inventions, but they cannot replace the judgment of the human brain. A computer can do only what it is ordered to do. The machine can carry out a number of instructions in programmed sequence, rapidly and automatically (and not talk back). But if a single one of the necessary instructions is omitted because it was not originally prepared by a human, the machine must be ordered to stop or its results will be useless or misleading.

Although electronic systems will revolutionize many business systems and procedures, help pull together fragmented responsibilities, provide a means for integration of decentralized operations, and eliminate many clerical and middle-management functions, they cannot provide a completely automatic administration. They cannot formulate and define the purpose of an organization. This will remain a function of human management. Computers are not brains.

Cost. As another result of the publicity given to the first scientific computers, many persons believe that these new devices are only of interest to firms which have several million dollars with which to experiment. Since most businessmen are accustomed to paying for office equipment in terms of tens of thousands of dollars, or less, they may conclude that this is all far beyond their capabilities.

It is true that the general-purpose large-scale computers, which have tremendous capacities, are expensive. But already there are many types of smaller and cheaper electronic systems, and more are being developed. Some very inexpensive models (under \$5,000) are designed for special purposes. Under development are smaller general-purpose systems which will cost considerably less than present large-scale computers; some will cost less than \$30,000. Yet the savings they can offer are significant. Moreover, most of the machines need not be bought outright; they can be leased. It is not even necessary that companies have the machines in their own offices. Service centers are being established where machines can be rented for a few hours a

day. Since the larger machines operate so rapidly, a few hours are sufficient to handle a large volume of work.

Types of Systems. It is extremely important that the businessman understand that there are many kinds of electronic equipment. Some can replace an entire tabulating-machine installation. Some can replace only a hand-posted file. Some can be used only to record the count of items. Others are only calculators. Some are sorters. Others can store data on an electronic or magnetic medium, such as a tape, or drum, and can reprint it when desired. All of these abilities can be had at different speeds for different costs.

Generally speaking, the more flexible and rapid the machine, the more expensive. Large-scale general-purpose systems, in which all types of abilities must be present, obviously cost the most.

Another misconception is that the machines are all so similar that the choice is largely "whether a company should go ahead now, not which system it should buy." But the individual businessman also has the problem of choosing a machine, or several machines, to form the data-processing system which best meets his particular needs. This decision, of course, will be reached in the same way that any capital investment decision is made. If substantial savings can be forecast, the task will be easier, but the details of the expected costs must be available. Proposals to invest in electronic systems must compete with each other, as well as with the alternative uses of capital which are always before management. The value of one new system as against another should be judged not only by the benefits and the amount of the expected saving, but also by how certain it is that such results can be achieved.

Boards of directors or top managers often like to see how a machine or system has worked elsewhere before they try it themselves. But while it is possible to wait and learn from others' experience, this is not as desirable an approach to electronic systems as it may be in some other types of cost study. In general, the reason for this is that each system must be tailored to individual company requirements.

The result of several studies has indicated that wherever more than a hundred clerical workers are engaged in computing, sorting, transcribing, or storage of data, a general-purpose electronic system merits consideration. Special-purpose information, such as recording an inventory situation, can be obtained by using special systems if the present expenditure or the added value of the information is of the

order of about \$15,000 to \$20,000 a year. Systems have already been accepted that call for a pay-off period of up to 5 years, because of other advantages in speed and accuracy.

A number of companies are already buying computer time on a service basis. Rates of \$100 to \$300 per hour are being quoted. Eventually, many more companies will be able to reduce costs through judicious use of this type of service. Rental use of computers is now a widely accepted practice for engineering calculations by companies whose own facilities are overloaded.

Preparation for Installation. There is more to be considered than the cost of the machine and the systems study. Personnel with many new types of ability must be hired or trained. A detailed description of the system type of data transferred, management needs, etc., must be prepared. The "engineering specifications" of the paths and rates of flow must be established.

This preparation was overlooked by one company. It was one of the first to order a large-scale computer, but it was forced to request postponement of the installation.

The computer must be told what it is to do in great detail and in a "language" code that it can understand. Of necessity the people who deal directly with the machine must be specially trained. Since most machines have heretofore been working on mathematical problems, the only groups who have had much experience in feeding data to machines have been the electronics engineers and the mathematicians. The first companies to venture into this field hired such men to advise them and to lead the way.

Studies and subsequent experiences have shown, however, that for data processing it is easier to train a businessman in computer abilities and requirements than it is to train a technical expert in business-system requirements. This means that usually it is advisable to take a capable man or a group from a present systems and procedures force and to train them in the use of computers. Usually this has been accomplished by sending the men to the schools now operated by the major manufacturers of computers. Schools such as Harvard, M.I.T., Wayne, and U.C.L.A. also have begun to offer computer courses.

Mathematicians take longer to learn the intricacies of a particular business system than systems men take to learn what they need to know about computers. In spite of this, however, men with some skill in mathematics can make a significant contribution toward the more

efficient use of a large-scale computer. Mathematical training is useful in formulating and stating the problem to be solved. A "program of instructions" for a computer—the detailed list of steps it follows in processing a group of data—must be logically complete, as must a mathematical solution. Moreover, as the company advances in its use of new methods of analysis, the presence of several mathematicians becomes all the more desirable.

Preparation of each "program" for a data-processing routine on an electronic computer takes more time than is sometimes believed. It is often a matter of several months rather than weeks. Each step must be studied by expert workers, and all possible exceptions considered. However, once the program is established, it can be stored in the computer itself, or in media rapidly insertable in the computer, so that it can be used over and over with a minimum of further study. In some machines part of the program can be changed, if it is desirable to do so, without losing all the benefit of the work already done.

Speed. The speed at which present electronic systems operate is another point commonly misunderstood. Certain aspects of their operational speeds are phenomenal. Some computers can perform thousands of arithmetical operations a second. But in some systems the original recording of the data is done no more rapidly than it is done at present. For example, most payroll applications of electronics now contemplated still use timecards, from which the data will be transferred to other media for entry to the computer. The day will come when counters and meters and other instrumentation will automatically record all sorts of information and transfer it directly to the computer. But this is still in the future for most applications.

Often the high speeds of computation which can be achieved are greater than are needed. For example, processing of payrolls in a large company now requires a number of days, partly because of the amount of computation involved. Electronic systems can reduce the time for computation to hours. Whether they reduce it to 4 or to 6 hours will rarely be significant. Speed of computation is not the only criterion for judging the effectiveness of these systems. Speed, moreover, adds to the complexity and cost of the electronic system.

Equally important is the speed with which data can be introduced and taken from the computer. At present several electronic systems print out information only six to ten times faster than the rate achieved by printers of the type in common use in punched-card installations.

Several very high-speed systems are under development, but there is a question whether one such printer will be better than several slower ones. In any case, substantial improvement over present methods is still fairly expensive, and much remains to be done.

In many business situations data are recorded in random sequence. Because large volumes of data are usually stored in serial fashion, on magnetic tapes, sorting speeds are important. Since sorting seldom was required for mathematical and scientific calculations, early computers were not designed to sort rapidly. A number of solutions to this problem have recently been developed, but equipment now offered is not always economical. The problem of rapid access to large volumes of stored information is receiving considerable attention from computer manufacturers, and will be discussed later in more detail.

In many types of application there is need for better balancing of the various capabilities of the systems before they can attain the speeds which are popularly believed to be available. Much work is now under way on these problems. Study is still needed also to determine the best combination of characteristics in order to handle business needs in an optimum fashion. A number of experts who have been studying the requirements of their particular companies are still far from satisfied with the equipment now on the market.

Obsolescence. This leads to another popular misconception—that computers now being offered will shortly be obsolete. Changes are expected along two fronts. There will be improvements in the over-all design, and in various components and parts.

It is true that the first models of any machines are inevitably experimental. Each manufacturer that builds a machine incorporates designs which reflect a particular viewpoint. In addition, machines offered commercially as a rule use parts which have been tried and tested, not the newer devices which offer considerable hope for improvement but which are not yet reliable.

As business needs are increasingly understood, as designs are compared and shaken down, and as parts are improved, present machines will tend to become obsolete. But before deciding to wait for better equipment, the buyer should consider several factors which tend to offset the fear of obsolescence. Tremendous sums already have been invested in electronic computers, and much of the first experimentation has been accomplished. Secondly, in many installations the immediate savings and increase in operating effectiveness will be sufficient so that

the systems can pay off the original investment long before economic obsolescence is likely to occur.

In addition, experience gained with the electronic system will reduce the expense of installing and using any new and improved system. This factor should be of real significance. Moreover, several expected improvements, such as the introduction of high-speed printers operating at over 1,000 lines per minute, can be tied to existing computers, so that only a portion of a system will be replaced.

If the user feels the danger of rapid obsolescence is too great, the equipment can be leased. Most manufacturers of computers make them available under reasonable leasing arrangements.

Much publicity has been given to diodes, transistors, and magnetic cores. Diodes are units that will pass current only in one direction. They are now used in some computers in large quantities—as many as 1,000 to 5,000. Engineers tend to overspecify in order to protect against machine failure. Even so, many types of diodes cost an average of only about \$.75 to \$2.00 each, so that if the cost were reduced substantially, the difference in the total cost of the initial system probably would not be too significant. Of course, more reliable diodes reduce maintenance costs.

Transistors are units which perform functions similar to vacuum tubes, but use less power and last longer. Reliable transistors are becoming available in quantity. Most computers will be equipped with them some day, it is presumed. Companies already are designing their computers to take advantage of transistors as they become more available. They also design sections which are only plugged into the original equipment, so that they can be replaced when better sections are available. Use of transistors will reduce costs, weight, power requirements, and need for air conditioning, but probably will not alter the data-processing capabilities of the machines significantly.

Magnetic cores, described in Chapter 3, offer a method of storing data where it can be reached in a few millionths of a second. Cores are more reliable than some other presently used devices, but they are not revolutionary in the sense that by using them the machines will obtain new types of ability.

The general conclusion is that these developments offer hope for improvement, but they are not likely to be a decisive factor in reducing the cost of most types of equipment during the next few years.

However, the electronic industry is one of rapid development. En-

tirely new concepts of logical design are being studied. Some day these may well enable manufacturers to produce general-purpose machines for significantly less cost than at present. The business user should find it advantageous to keep informed of these developments.

Accuracy and Dependability. As with any business machines, managers are much concerned with the accuracy and dependability of the electronic system. Because of early difficulties with electronic computers put together by experimental groups, it is often mistakenly believed that computers are not too dependable, that they break down frequently.

Machines may use as many as several thousand tubes and circuits, and though the percentage of failure is low, instances of failure may be fairly frequent—perhaps several a week. However, the engineers of manufacturing companies are well aware of the problem and have incorporated a number of solutions in their computers.

Computers are now being built with plug-in or “modular” units. Testing equipment often is made part of the computer itself. Tubes usually weaken before they fail, and this weakening often can be detected. As a result, troubles can be located as part of routine maintenance. The offending circuits can be removed and replaced in a matter of minutes. Stores of these parts are maintained at the computer or are available from the manufacturer. A few hours of preventive maintenance at regular intervals minimizes unscheduled down time.

Scientific computers have been improved considerably in recent periods, so that along with scheduled preventive maintenance of about 10 per cent of the time, unscheduled breakdowns have averaged less than 10 per cent of the time. Several large commercially built computers have not been down unexpectedly for more than 4 hours at a time since installation, although they are working around the clock.

Many businessmen are worried lest their records be lost in an electronic system. Some types of record are lost if power fails. If the data are in these types of storage devices, the sources of information should always be recorded elsewhere, in types of storage that do not fail if the power goes off. Then the information always can be reproduced.

Data on magnetic tapes and drums do not disappear if the power fails. Still, since the data are in the form of magnetic charges, they may be erased from tapes or drums inadvertently by stray electric shocks. To protect against loss from such accidents a complete repro-

duction of all information in the system can be run off periodically and transferred to safe storage. If any disaster occurs, the company can back up and start over. Running off the duplication (which is placed on magnetic tapes similar to those used for sound recording) is not complicated, time-consuming, or overly expensive.

Engineers have made considerable efforts to achieve the accuracy required for accounting and auditing standards. A number of checks have been devised to test the operation of commercial computers. As a result, in some ways electronic systems already are more accurate than any other type of data-processing system. Some can make long series of numerical calculations with no errors that the machines themselves fail to catch. Of course, if wrong information is introduced, it will be repeated, but even here certain automatic checks can be employed. For example, the machine can be instructed to refuse to accept nonexistent inventory code numbers that a human tries to enter.

On the other hand, the effect of some types of errors in the system may be serious. Fewer human observers scan the data as it is processed. Electronic systems usually are less fragmented than are decentralized clerical operations, so that the effect of an error has somewhat greater chance of becoming compounded. However, practical safeguards against this also can be devised, using intermittent print-outs, or using the high speed of the system to cross-check and repeat.

In general, computers have shown themselves to be highly accurate, making considerably fewer mistakes for the same amount of work than do other systems. They have made some mistakes, but workers believe that most of them have been detected.

Summary of General Concepts. Electronic systems are great inventions. They now offer considerable benefits to business users, even though they are not brains endowed with judgment. They are fast, accurate, and dependable. Present machines will not become obsolete overnight. The cost is not unreasonable in view of the service and savings which they can provide to business. The benefits are there for those who are willing to learn how to use them.

THE GENERAL-PURPOSE ELECTRONIC COMPUTER

To this point we have been discussing the general concept of electronic data-processing systems. As was indicated, there are a variety of electronic devices available for data processing. Some are large-

scale general-purpose computers, some are smaller scale, others are special-purpose electronic devices. In order to help the reader to distinguish sharply between a general-purpose computer and the less extensive electronic devices, this section will attempt to describe in general terms how a large-scale digital computer works.

The word "digital" refers to the fact that the machines considered for accounting and other business data-processing needs usually are of a type which records, computes, and reports in terms of absolute digits, like a desk adding machine. Some electronic machines are "analog"; like a thermometer or speedometer, they can indicate only approximate figures. The analog computer has many uses in engineering, where it can simulate physical conditions, in utility power grids, flight conditions of airplanes, and so on. There have been suggestions concerning possible applications to economics and business. This will be investigated later; meanwhile, the system discussed is "digital."

The basic concepts involved in the description of digital computers can be grouped as follows:

1. *The components.* These are the functional units which are grouped to form a general-purpose electronic computer. Several mechanical devices may be grouped as a "component."
2. *The functions.* These are the operations carried on by each of the components; the type of work each performs.
3. *The devices and media.* The devices are the mechanical units which carry out each of the functions. Usually the devices are categorized in terms of the "media" they use. "Media," such as tapes, or punched cards, hold the data while they are being processed or stored. The distinction between a "device" and a "component" is somewhat arbitrary, but here the larger units will be called "components."
4. *The operating characteristics.* The different capacities and other characteristics of the devices, such as their speeds of operation, bulk, etc., are called "operating characteristics."

A large-scale digital computer has the following major components: input, processor, and output. The organization of these components can be compared with the operation of a desk calculator. The keyboard of the calculator is the "input," the mechanical counters perform the arithmetic and storage functions of the "processor" while the operational keys provide control, and the dials are the "output."

In the electronic system all these units are electrically connected so that data can be transferred between them. Figure 1, a simplified diagram, gives an indication of this linkage.

Table 1 shows the interrelationships of these concepts in a more elaborate fashion. Most large-scale computers have all of the major components listed. They usually offer different devices to carry out each function, which gives them varying operating characteristics.

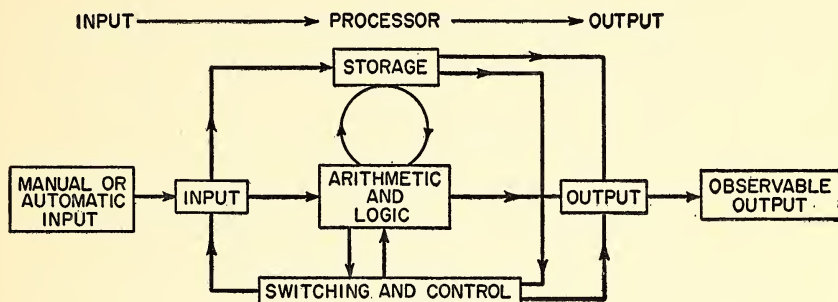


FIGURE 1

How a Computer Works—Input. As in any other manner of data processing, the first operation is to record the data. If this original record is not made in a form which the computer can handle and read, the record must be converted onto media which can be used as input. Special devices are available to handle this operation. Input to the computer is usually thought of as comprising the original recording of the data, the conversion to other media if necessary, and the actual transfer of the data into the processing component.

Large-scale computers usually are not directly linked to the point of original recording of data. Source documents of the type now used still must be prepared. The data from these documents usually must be transcribed, either simultaneously or later, on media such as magnetic tapes, or paper punched tapes, or punched cards. This must be done in a manner which can be read by the computer. In other words, the data must be placed on the media in a form which is the "language"-symbol system of the computer. (See Appendix 1 for discussion of the language of the computer.)

Print readers, which will translate properly printed material, are now coming on the market. Other devices prepare and read input in the form of coded dots, etc. Once the data have been transcribed

TABLE 1

Components		Functions	Media	Operating characteristics		
Input	Record			Speed to * record	Speed to * read-in	Bulk
		Transfer data to media that system can read	Magnetic tape	3,000-10,000	10,000 +	Not bulky.
			Paper tape	30	30-600	Fairly bulky.
			Punched cards	150	150	Bulky.
	Read-in	Transfer data into computer	Printed-typed material	3-5	5	Bulky.
Processor	Control	Transfer data inside computer	Circuits, tubes, diodes, transistors, and other electronic equipment	Basic speeds a few millionths of a second for each step of an operation. Each operation such as "add" takes several steps. Various systems have various speeds. Some only 1 a second.		
	Arithmetic and logic	Add, subtract, multiply, divide, compare, sort, test				
	Storage	Internal storage in computer where data are available for process				
Output			Magnetic core, electrostatic, acoustic delay	Very fast. Many thousand per second.	About 20-50 cubic feet.	
			Magnetic surface drums, tapes, cards, and paper tapes	Quite fast—several thousand or hundred per second. See input.	15-30 cubic feet, varies greatly.	
	External storage	External storage for data not presently needed by computer	See input	See input.	See input.	
	Print-out	Preparation of data in forms useful for business purposes	Printed paper	150-1,000 lines of 120 characters per minute.		Desk size.

* Characters per second—rough averages of several systems.

onto the input media, the source documents are never again required, except possibly for auditing purposes. In effect, the data are ready to go through a production line, each stage of which can be controlled automatically.

The manner in which the data flows down the production line is governed by the control element of the processor.

Control. The control device determines whether the computer is to read input, or to add or subtract, or where to store results, etc. In order for the control element to operate, it must be given a prepared list of instructions. People who deal with computers call this set of instructions a "program."

The program is stored in the computer in magnetic or electronic form, just as is the information to be processed. The program is entered via the regular input. When in the computer, the program governs the operation of the circuits. It tells the mechanism when and how to perform each individual step in the routine which is being performed.

The program must instruct the mechanism which item to read off the input media, where to transfer it, what to do with it (for example, to multiply it, etc.), and where to put the result. If any single instruction in the program is not correct—and some programs have thousands of steps—the machine will stop or give incorrect results.

Logic and Arithmetic. The processor takes instructions from the program. It can transfer data from one part of the computer to another. It can compare numbers and choose its next operation by jumping to different steps in the program automatically as a result of the comparison. One small example: while posting requisitions of inventory, it can initiate a purchase order if the inventory balance falls below the stored reorder point. Another useful ability of the logic device is to let the control component know when the computer has reached the end of a routine; it will automatically start the next sequence or stop the machine.

The control tells the arithmetic unit which mathematical operation to perform, at what step in the process. The arithmetic element can add, subtract, multiply, and divide, shift decimal points, round off numbers, etc., and temporarily store results. In general, these operations can be performed at the rate of several hundred to several thousand computations per second, depending on the size of the machine.

Storage. Storage is the holding of data for later use in the operation of a computer. The input stores data in forms that can be brought to the computer. It transfers the data to temporary storage locations in the computer or directly to the main storage device.

The major types of internal storage devices usually are classified according to their speed-of-access time. This "access" speed is the length of time required to locate a storage address and to place an item in, or to take an item from a storage unit and to make it available to another part of the computer. Some types of storage are "serial"; for example, the items on a tape reel can only be reached at high speed in their recorded order. The length of time it takes to reach *any* item of information, no matter where placed in the storage, is spoken of as the "random-access" time. Obviously, random-access time is of great importance for certain purposes. For example, with high-speed random-access storage there is no need to sort input. Generally speaking, storage units with high-speed random access cost more per unit of information that they can store. As a result, only a limited amount of such rapid-access type of storage has been built into present computers. High-speed storage devices include electrostatic tubes, acoustic delay lines, and magnetic cores.

Moderate random-access speed, to greater volumes of stored information, is available economically on magnetic drums and magnetic tapes. To give a rough indication of speeds of access to stored data, some magnetic drums can provide information in a few thousandths of a second, while electrostatic storage or magnetic cores can provide data in a few millionths of a second.

Because the arithmetic and logical units operate so rapidly, speed of access to stored data is of prime importance for efficient operation of the present types of computers. Since most computers refer to their stored program of instructions at each step of the operation, the overall speed of operation can be no faster than the highest access speed to such storage.

Output. The results of computation can emerge either in a form suitable for record storage in the system, or in a printed form. The former type of output is often placed on magnetic tapes similar to those used for input purposes. The tapes can be stored as they are, or the data can be transferred automatically to punched cards at the rate of more than a hundred cards a minute.

A variety of printers are in use. Some were developed long before computers were perfected. Examples are electric typewriters (six to

ten characters a second), and line-at-a-time printers such as those used in punched-card systems (100 to 150 lines a minute). High-speed printers, under continuing development, print up to a thousand lines (100 to 130 characters each) a minute from either tapes or cards. Photo devices record several thousand characters a second.

The program of the computer can control the format of the printed product, so that reports used by business can be prepared automatically in any form desired which is compatible with automatic printing. Most systems provide separate printers, so the main computer is not tied up during the printing process.

ILLUSTRATION OF THE OPERATION OF A COMPUTER SYSTEM

As can be seen, the operation of an electronic computer designed for processing business data is not easy to understand. However, it is possible to follow the major stages of the operation by means of a simplified illustration, such as the one which follows.

Suppose a company wishes to place its inventory accounting on a computer. Assume that the problem is merely (1) to record an opening balance, (2) to record the subsequent purchases and sales and (3) to compute current balances each day, including the ending balance, and (4) to make this information available as required.

Suppose the company records increases in inventory on the basis of invoices after confirmation by receiving room reports. It receives notices of sales from the sales department as sales orders; the assumption is made that all orders taken result in shipments.

Conversion from present equipment to the electronic system is a problem which will be discussed later in the book. For present purposes, let us assume that the company in effect is starting an entirely new operation, with no inventory on hand.

Input. Each item of inventory must be given a code identification, as in many present systems. When an invoice arrives, plus a receiving report showing, for example, that 11 units of item No. 356 have arrived, unit cost \$5.00, the information is sent to a girl who types it on a regular typewriter keyboard. The machine she uses, however, not only types the information on a standard form, but also automatically translates it into a series of electrical signals, which are placed as magnetic charges upon the surface of a tape coated with material that will store the impulses. (Or, the medium used might be paper tape, in which case the machine would perforate the tape as the girl typed.)

After a suitable amount of information has accumulated on the tape, it is taken from the typist and placed upon a device which feeds the tape past a reading head, much as sound tape is fed past a reading head on a sound-tape recorder and player.

We now have the "input" ready for action.

Processor. However, before the computer can operate, the machine must be "instructed" as to what it shall do with the information as the data are read by the reading head. These instructions, of which there will be many even for a process as simple as the one we are describing, are the "program" of the machine. An analogy to a computer program is the wired plugboard of a regular punched-card machine, which routes the impulses read off the card, and thus achieves the desired arithmetical operations and transfer of other information. But the analogy is not exact. A computer program is a list of commands which are stored in, can be modified by, and are carried out by other parts of the mechanism. They are not a "way routing," such as is the plugboard.

Assume that we store a list of instructions in the machine. The first of these instructions will be, in effect, "Read the number that is under the reading head." Thus the code No. 356, identifying the type of inventory item, will be read as it comes under the reading head.

Next, a subsequent instruction (or part of the first instruction—machines vary as to how many parts there are to each instruction) will tell the computer, in effect, "This number is the same as that given to a storage position (address) in the computer's storage. Connect your circuits with that storage position and read out the total number of items shown to be on hand at present." This instruction is analogous to telling a clerk to go to a file drawer (No. 356) and to copy the current balance, in units, from the inventory card. In this case, it has been assumed that this current balance is zero.

When the amount of items on hand—zero—is determined, it is transferred to a temporary storage position in the arithmetic part of the computer, where it is available for computation. This temporary storage position is often called a "register." A register is an electronic circuit that can store an item of information, such as a number or an alphabetic character, and make it rapidly available (in a few millionths of a second) when again needed. All general-purpose computers have such registers.

Now the program tells the computer to read the next bit of infor-

mation on the incoming tape. This is the fact that "eleven" new items have been received. The program tells the circuitry to add this amount to the "zero" stored in the register, and place the sum back in address position No. 356 in the storage. The equivalent manual operation would be to have the file clerk transport the number to another clerk, who added the two items on a comptometer and gave the answer back to the file clerk, who placed it on the card and returned it to the file.

The system described would be sufficient if all that were wanted was a straight unit count of the inventory balance. There are actual electronic systems now in operation which do about this and no more.

However, if information concerning dollar values is also wanted, the electronic system can handle this too. The machine must be instructed to hold the "eleven," which it has just read from the tape, in the register. Thus it is still available for computation, even though it has also been added to the previous unit balance. Then the machine is instructed to read the unit price from the tape, \$5.00, to multiply the "11" by "5," and to add the total, \$55.00, to another part of address position No. 356. Of course this means that the storage position must have been previously subdivided, say into No. 356.10 and No. 356.11, etc., so that the machine will not confuse the units count with the dollar total.

Sales can be handled in the same way, except that the machine would be instructed to subtract. The typist would prepare the tape containing the sales information in a fashion similar to the tape for the purchases. It is even possible to have purchases and sales mixed together on the same input tape; the sales would be given an identifying code that differentiated them from the purchases, so that the appropriate computation could be made.

The system described above assumes that the storage can be searched in random fashion, as a file clerk can search a set of files—that is, it can go to any one of the "drawers" at random. "File computers" using sets of drums or discs can do this. Other systems of electronic or magnetic storage now in use, while large enough for the use of tables, or listings of a few thousand items, are not large enough to handle in this way the many thousands of items of inventory customarily found in business.

This means that a system of storage on tapes may have to be used, which in turn may mean that the items must be brought to the computer in a sorted order. As item No. 356 comes in on the purchases

or sales "input," the No. 356 storage position will be made available from the tape storage, and the operation can proceed as before. This is like having all the incoming items sorted in numerical order, so the human clerk can walk through the files in a straightforward fashion, without retracing his steps, inserting new computations in the files as he goes.

Output. Since the information concerning the inventory is stored in the form of electrical signals, or magnetic charges, on various types of storage media, it is necessary to have some means of making it available for humans to read. This is accomplished by adding a printer to the system. This device can operate from the computer and, in effect, can reverse the process that was used to record the data as they were typed from the invoices and other papers.

The above system is highly simplified. A great virtue of these machines is that they can do so many things automatically. For example, as part of the instructions, the machine might be told that when a sale is made from storage address No. 356 the machine should examine the lowered balance and compare it with a minimum balance for that item, also stored in the system. If the sale takes the balance below this minimum figure, the machine can note that fact in a separate storage location, which can be used to print out a list of such items for the attention of the purchasing department. Or, if the name, address, etc., of the usual supplier and the standard order amount are stored in the computer, it can print out a purchase order automatically.

The process of comparison is carried out by the logical circuits of the machine. In essence, the machine can take a number from one location, another number from another location (the latter may even be a computed number, as in the example), and subtract one from the other. If the first is the larger, or the two are equal, the machine will do one thing (that is, go on to another item). If the second is larger, so the difference between the two amounts is a negative number, the machine will do a different operation (that is, list the item as having fallen below the minimum balance, then go on to another item).

To illustrate a still more complicated procedure, suppose that the managers would like to use the "moving average" method of inventory calculation. This procedure has always been too time-consuming for widespread acceptance. But it is a simple matter for the computer. It can be instructed to add a new purchase to the old (both the number of units and the dollar figures), to divide the new dollar total by the

new unit total, to calculate the new average unit price, and to use this new average unit price for any subsequent sales reductions of inventory.

The arithmetic and logical components of the computer are so efficient that manufacturers have advised potential users to think in terms of operations even more complicated than this. For example, it is not only feasible but efficient and economic for a computer to work through a group of insurance policies, calculating anew the dividend available on each. In other words, it can do the computation for each policy separately according to a complicated actuarial formula involving dozens of factors. The computation would only take a fraction of a second, and is more efficient than storing a large table of precomputed dividends.

INTERNAL OPERATION OF A COMPUTER

There is some debate as to the amount of information which an executive should have as to the internal operation of a computer. Some argue that, as with a telephone or an automobile, it is not necessary for a user to know much of the physical attributes of the system in order to use it efficiently. Others point out that even these relatively simple devices perform more efficiently for the user who knows why he should wait for the dial tone or keep oil in the crankcase.

There is nothing weird or fantastic about the operation of an electronic computer, although it is a very complicated mechanism. The more an executive understands about the principles of operation, the better will he be equipped to assess the recommendations and suggestions which he will receive from his staff advisers concerning the installation and use of electronic equipment.

A brief introduction to the internal operation of the computer is presented in Appendixes 1 and 2, under the headings "The Language of the Computer" and "Programming."

Electronic Storage. One of the simplest, yet most disturbing, attributes of the computer is its ability to store information in a form which cannot be seen or felt. Yet it is more permanently and safely recorded than it would be on the more familiar medium, paper.

The basis for this record is the fact that material can be magnetized or that electric currents can flow in two different physical states. Magnetism can be placed directionally, i.e., either the north or south "pole" can be "up." Properly magnetized material appears to maintain

this state indefinitely, and will withstand conditions that would destroy paper records.

Since there are these two discernible states, they can serve as symbols. If "north" up is considered to be "zero," then "south" up would be considered to be "one." On this basis it is possible to record combinations of "zeros" and "ones." These can be coded to be the equivalent of any combination of decimal numbers, of alphabetic characters, of punctuations, of placings in report forms, and so on. The symbol system is not efficient—it takes a good many "0"-"1" symbols to represent our more usual numbers and characters, but the machines can transfer these symbols at the rate of 186,000 miles a second and store them several hundred to the inch along a tape and in several channels across a tape. One computer design calls for a 31-channel tape, 2,800 feet long. One reel, which would about fit in a case for a portable typewriter, will hold the equivalent of over 400,000 punched cards.

Electronic Processing. Another major attribute is the ability of the computer to transfer these "0" and "1" symbols in such a way as to perform addition, subtraction, or the other processing steps which have previously been described. This ability is derived from the physical characteristics of certain electronic devices. One of these is the familiar vacuum tube, or its cousin, the transistor.

A vacuum tube or transistor has three principal elements. Lines lead to each of these. A current coming in line No. 1 can come out (often amplified) on line No. 3 only if the proper signal is present on line No. 2. Thus the line No. 2 acts as a switch. By proper combination of circuits, it is possible to have these switches allow currents to pass only when the computer program signals that it is desired.

The designer of the system builds his machine so that a certain signal will always cause the circuits to add incoming signals from specific locations. Another signal causes the circuits to place the result in a specific location. And so on.

The designer provides the user with a list of these program signals, called "instructions" or "commands." Because these instructions are so simple, each one dealing with a very specific detail of an operation, it takes a fair-sized number of them to perform even the most simple processing of data. Moreover, the same end result can be built up in a number of different ways. This means that one program can be much more efficient than another. Even though the machine operates

very rapidly, if it must perform a routine many thousands of times, the differences in time may add up to a costly amount, especially when the alternative uses of computer time are considered.

There are many ways to approach the problem of programming an operation. One is to study the situation until the analyst can set up a "flow chart" showing the major operations which must be performed. Then he studies each of the operations to determine which elements must be repeated. An example might be the step which must be taken each time a sale is recorded.

A series which will be repeated is called a "loop." The programmer attempts to make the machine perform the loop as efficiently as possible, since it may have to be used many times.

Then he links the loops by providing a transfer command. The machine will leave one loop and go to another set of instructions whenever a planned situation occurs, such as a comparison of two numbers that results in a negative difference.

After going through a number of loops, the last transfer may send the machine back to the first loop again, using new input, so that the whole process can be repeated. In this way the machine can be set up to work automatically through a complete record of a day's sales, or of the plant payroll, giving each of the like items similar treatment.

It is evident that skilled programmers are one of the more valuable assets a company can possess when installing and operating an electronic system. Many firms have spent thousands of dollars per man to educate their employees in the art of analysis and programming. (This figure includes the salary while learning.) Many companies are contemplating the establishment of analysis and programming teams of 10 to 15 men. The larger companies have 30 to 50 and even more. Obviously the investment in this aspect of electronics is considerable, even apart from the cost of the equipment.

SUMMARY

The preceding sections have dealt in a general way with the abilities of electronic computers and have explained the importance of a program.

The fundamental logical principles of a digital computer can be summarized as follows:

1. Characters (either numbers or letters) can be represented by electric signals. In a digital machine, these signals can be used to represent the characters precisely, so that the characters can be transferred and reproduced as originally recorded.
2. Arithmetic operations and certain logical operations, such as comparison and choice, can be performed by electronic circuits.
3. The operations can be controlled automatically by instructions stored in the form of electric signals.
4. The instructions can be coded as alphabetic characters or numbers.
5. The signals for the characters can be stored electronically or magnetically.
6. A stored program of instructions can be used to control a sequence of arithmetic and logical operations.

These principles make it possible for business to develop systems which have the following general characteristics:

1. Consolidated files.
2. Use of predetermined standards, for comparisons.
3. Simultaneous processing of data for different purposes, eliminating intermediate steps.
4. Provision of exception data as required.
5. Integration of data-processing and reporting systems.

Some knowledge of the way computers operate—their “language,” circuits, components, media, and so on—is necessary for the nonexpert who wishes to use electronics for business applications. Understanding the technical features and limitations will help him in the selection, installation, and establishment of realistic schedules. In addition, the need for a “team approach” to electronic-system application will be appreciated. Members of the current planning and procedures organization should be called upon to help the team with their knowledge of the company’s systems, as well as with their expert skills in various areas, but they should not be expected to carry the burden alone.

The complex nature of electronic computers, as evidenced by their complicated circuitry, indicates that large-scale computers will not become cheap overnight. But their price will come down as newer methods of design appear and as production costs for components and for assembly are reduced.

A systems and procedures group can do a great deal to prepare for future use of a computer, long before the installation is actually made. With an understanding of the requirements of electronic systems, they can incorporate in their current studies the type of detailed description of the operations which must be set down before a program can be prepared. They can even prepare a program, test it on a machine rented for a few hours or days, establish standard subroutines, and so on.

Programming a computer is painstaking, detailed, and exacting work. Unfortunately, the computer is not a self-starting, self-determining "brain." The computer cannot analyze and digest data, except in so far as its stored program and built-in logical component tell it how to do so. Each step of a complicated business procedure must be analyzed into the sequence of specific operations that the computer can perform. The resulting program must be coded into machine language and stored in the computer before it can be used. This means that a crew of programmers must be trained as to the requirements of both the computer and the business system. Also that they will require time to actually program the system after they have learned their job. It cannot be done automatically or mechanically, although sometimes subroutines can be reused for more than one application.

On the other hand, the logical operations which the machines can perform create opportunities of real importance. Clerical and analytical routines which consist of comparison, or arithmetic computation, or signaling of maxima or minima, etc., can be performed by the computer. The computer will make analyses with tremendous speed and with reduced errors and cost, compared with clerical help. The proper use of the logical and arithmetical components will help open the way for adoption of methods of control and analysis which have never been attempted before, because they were obviously not feasible without the assistance of a computer or without extended training of middle-management personnel.

The next step in our discussion will be to investigate in more detail the operations performed by each of the components.

CHAPTER THREE

Survey of Electronic Methods of Data Processing

Certain fundamental aspects of electronic systems make the systems substantially different from any data-processing methods heretofore used. (Of course, it should always be remembered that they can be linked with older systems, especially with punched cards.) But this does not complete the problem posed by the advent of electronics. The possibilities offered by these new inventions are so broad and varied that there is no single machine on the market which embodies all of them. It is difficult to select the equipment best suited to a business' needs.

There are a large number of companies—over two hundred—which are interested in the electronic field to the extent that they supply parts for the computer systems. There are more than a dozen which are building computers. Some have been conducting experiments and are still determining what they wish to offer commercially. Others have definitely committed themselves to certain types of design, have built systems and components, and are offering them for sale.

Until a prospective user has made a survey of the field, it is difficult for him to assess the particular systems which may have come to his notice. There is a bewildering array of ideas and "hardware" (machines and equipment) which are offered or talked about. Few experts are available for advice who are not working for one of the manufacturing concerns, although accounting firms and management consultants are studying the field intensively so as to be able to aid their clients.

In addition, many businesses already are conducting much of their data processing with fair efficiency, or much of it may call for personal contact, so that only limited areas may exist for the use of elec-

tronics. In some cases scheduling of production, or reporting for central purposes, or rapid access to an up-to-date file of information, etc., is the major problem which needs solution. For these companies a limited use of electronics, embodied in a "special-purpose" system, may be economically advantageous.

Because available electronic equipment is so varied, it is not feasible to describe all the devices individually. A study of needs and of related electronic possibilities must be undertaken by each business on an individual basis. This will require, on the part of the purchaser, an understanding of some of the technical aspects of electronic media and devices. In general, it is usually possible to think of the processing requirements of a company in terms of the amount of raw data which must be recorded (input), transmitted and manipulated (processor), and the reports and records which must be prepared (output). For this reason, a better understanding of the components of an electronic system should prove helpful to the businessman.

INPUT MEDIA AND DEVICES

As mentioned in the previous chapter, there are three major types of input media in use: magnetic tapes, paper tapes, and punched cards. In addition, there is direct input from keyboards and from automatic devices.

For a high-speed computer to operate efficiently it must be equipped with high-speed input equipment. The machines which offer the highest input speeds at present use the magnetic tapes. Magnetic tapes can feed data to the processor unit in some systems at the rate of over 15,000 characters per second. Several systems operate at about 10,000 characters a second, which is many times the speed of punched cards or paper tapes.

However, the rate at which data can be recorded by humans on any medium, including tapes, is limited by manual typing speeds—about six to eight characters a second. For this reason, manufacturers are working on systems which will prepare tapes as the data are typed for the first time, thus avoiding repetition of this slow and costly bottleneck.

When the information is on punched cards or paper tape, it can be transferred to magnetic tapes. Special devices can accomplish this at about 100 to 115 characters per second, the limitation being due to the speed of handling the cards or paper tapes.

Tabulating Cards. Where a company already has a tabulating-card system, it may prefer to continue using a large part of it. In particular the company may continue to collect the information, to place the information on cards or on paper tapes, to verify it, and so on, before entry is made into the electronic system. This will be especially true where there is no pressing need for immediate up-to-the-minute information. Where the company wishes immediate knowledge of the status of an account, or of the location of a car of merchandise, etc., direct inputs may be necessary. Nevertheless, punched cards retain many of the virtues in an electronic system which have made them so widely accepted for mechanical processing.

A typical punched-card system operates with machines driven by electricity, but this does not make it an electronic system. As we have shown, in an electronic system the data are transferred, computed, and stored in the form of magnetic marks or electric charges. In the older punched-card machines computation is done mechanically, much as in a desk calculator. The instructions for these machines are fixed by wired control panels. They can be changed only by removing one plugboard and inserting another or by rewiring the panel. In this way they differ considerably from a general-purpose computer, which can store a large number of instructions and can change part of the instructions in accordance with other stored instructions.

Card Programmed Calculators now available might be considered an intermediate step between the older mechanical machines and the newer electronic computers.

Magnetic Tapes. Magnetic tapes are useful where the quantity of information to be handled is very large. Not only are they one of the quickest known ways of entering information in an electronic computer, but they are one of the best means of storing very large quantities of information in the least amount of space and at least expense.

Magnetic tapes used in electronic systems are similar to those used in sound recording. The tape backing may be of plastic, metal, or paper. The surface is coated with magnetizable material, a sort of paint of iron oxide particles. It is necessary for the coating to be complete and even, for a small gap in the coating would lose information, which may be placed as closely as 200 magnetic marks (representing binary bits *) to the inch. For this reason the tapes are not

* Binary "bit" is the name given to the "0" or "1" which together constitute all the symbols used in the binary system of counting. See Appendix 1 for de-

inexpensive. By the time they have been tested they may cost as much as 3 to 5 cents a foot. However, a foot of tape can hold a great deal of information, the amount depending on the way the information is coded and grouped. And the tapes can be reused many hundreds of times, whereas paper tape and punched cards must be replaced by new tape or cards.

A magnetic tape is usually apportioned into a number of "channels," which are longitudinal divisions. Generally speaking, each channel is read by a separate head in the input device which transfers the information to and from the computer. The heads are tiny electromagnets. Current passing through a coil sets up a magnetic field in the channel underneath it, on the tape. Or, a magnetized area already on the tape, passing rapidly by, induces a pulse of current in the coil; the pulse is amplified and taken into the machine. Another head usually is provided to erase the mark on the tape when desired. A character, comprised of several binary bits, frequently is recorded across the tape through use of several channels (as is done with the holes in paper tape for teletype).

Other Media. A drawback to the use of most input devices of computers at present is that the information must be transferred from the original paper evidence, such as the invoice. Under development now are input devices which will automatically scan printed data and activate magnetic tapes. Methods of using specially prepared cards or other media are under consideration which will reduce the time and cost of transcribing the information. Mark-sensing punched cards may speed up the input if they allow for bypassing the key punch. Typewriters with special attachments are available for recording data either on cards or on paper or magnetic tapes at the same time that invoices or other source documents are being prepared; the cost of these devices is approximately \$2,000 to \$4,000 per unit. While they may not reduce present primary clerical costs, they do provide the data in a form which can be used by the computer without further processing clerical cost.

In addition to these devices there are a number of others which have been investigated, some of which show considerable promise. Among these are point-of-sale recorders such as cash-register attach-

ments on how combinations of "0" and "1" can be coded to represent numbers and the alphabet. A similar "two state system" is the Morse code. All numbers and the alphabet can be represented by combinations of dots and dashes.

ments which will automatically prepare paper tapes as the register is used. Portable paper-tape punches are being employed to prepare input of inventory information at store and warehouse locations. The teletypewriter is being used to transmit input data over distances; the paper tape which comes off the receiving station can be read by a computer. In the department-store field, prepunched tags have been developed which can be used to transfer data to tapes or cards. In a document-sorting application a holder has been developed which can be read and sorted electronically while other information concerning the document is accumulated on tapes.

Special devices are available which convert rotation speeds, temperatures, and similar data into digital form which can be recorded on tapes or read directly into the computer. Other devices which can read directly into the computer include such items as keyboards, turnstile and other counters, and dial telephones. A class of devices, already much in use for scientific measurements but not as yet adapted to business-data processing, comes from the area of telemetering. These devices transmit data over distance using high-frequency radio signals.

Input media can be used for storing information. Magnetic tape can store more data within a given space than either punched cards or paper tape. For example, 1,500 feet of seven-channel tape can hold the equivalent of over 45,000 punched cards. The cards would require several file drawers. A seven-channel tape reel is less than a foot in diameter and less than an inch thick.

After the data have been originally recorded on tape or cards, the media must be placed in a reading unit. Magnetic-tape-handling devices can read (and write) information at high speed—some at over 15,000 characters a second—if the data are sorted in an order that the computer can use. If not, some tape-handling units can search for a particular item on the tape. This means the tape unit must read in both directions; interlocks are provided so that the unit will not try to read until it has found the address of the item wanted. Tape searching is usually slow; if items are widely separated on long tapes, it may take over a minute per item.

Paper-tape input readers are of two kinds: those using mechanical brushes and those using photoelectric cells. The former are similar to teletype readers and operate at the same speeds—about 10 characters a second. The latter have operated at speeds of over 600

characters a second. They are now being offered for a few thousand dollars a unit.

Internal Input—Storage. Not all the data on which the machine operates need be fed into the system from the outside. A great deal of information may be stored in the computer, so as to have it available on very short notice—a small fraction of a second. Other data which are only used occasionally can be stored separately and placed on the reading device only when they are needed. An example would be payroll information kept on a set of magnetic tapes which could be removed from the computer except when the payroll is run.

A program of instructions for the computer can be handled in either of these two ways: It may be kept in the machine if it is to be called on shortly, or it may be stored externally if it is not to be used in the near future.

STORAGE DEVICES

Storage, or the “memory” of computers, is one of the most interesting of the abilities of electronic data-processing systems. Fundamentally, a memory system is a method for delaying information until it is desired at a later point in time. To accomplish this requires a physical system which can hold a state indefinitely, subject to rapid read-out, or which can delay the transmission of a signal.

The delay period can be brief. It need be only a fraction of a second if the signal can be reconstituted at the end of the delay period and fed back to start a new cycle. This can be repeated many times, thus achieving the extended period of memory frequently required. (It is believed by some that the human brain cell operates in this fashion.)

Paper tapes and punched cards are efficient memories in the sense that they are a physical state which can retain symbolic data for long periods with no need for reshaping and strengthening the record. However, the read-out is comparatively slow and the information stored cannot be changed in the memory.

There are a surprisingly large number of ways to store information magnetically or electronically so that it can be read out rapidly and so that the information can be changed if desired. There also are other compact storage media, such as photographic film, where the data can be read rapidly but which cannot be erased and reused.

Most machines have "registers" which store the data temporarily as they pass through the computation centers. These registers are in the form of vacuum tubes, diode combinations, condensers, magnetic cores, or other devices. However, registers are limited in capacity and are not usually considered as "storage." Rather they are used as part of processing, or as "buffers"—delay points to accumulate data at input and output.

Magnetic Cores. One of the best of the high-speed memory media is the magnetic core, which is a small doughnut of magnetizable material. The cores are wired together. The result looks something like a wire window screen with a tiny metallic ring looped wherever the wires cross, except that the wires are not permitted to touch each other.

The ring-shaped metallic doughnut can maintain magnetism in either direction (see Figure 2). It has an interesting magnetic char-



FIGURE 2

acteristic (technically called a "hysteresis loop") in that the core resists attempts to change the direction of magnetism, up to a point. Beyond that point, when the core is exposed to a force trying to change its direction of magnetism—a force greater than an ascertainable amount—the core will suddenly reverse its field. It will then resist an attempt to change it back, until subjected to sufficient force.

A set of cores can be wired in a matrix (only part shown of many wires and many cores) (see Figure 3).

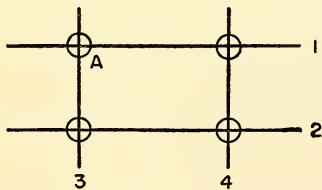


FIGURE 3

If a charge of a certain size is sent over wire 1, none of the cores will change direction of magnetism if the charge is below the amount they can "resist." If a charge is simultaneously sent over wires 1 and 3, then only core A will reverse field, since it is the only core to receive

a double "dose." The reversal can be detected by the circuitry. This setup can be used to store a binary bit of information in each core

and read it out when desired, by means of the instruction "address," which tells the computer which core or cores to locate.

Core memories holding the equivalent of over 20,000 alpha-numeric characters have been built, in which the random-access time is 3 to 15 millionths of a second. All the manufacturers of large general-purpose computers are using or contemplating the use of core memory.

Other High-speed Storage Devices. Another form of rapid-access memory is the acoustic delay line. A pulse is fed into one end of a column of mercury. It travels to the other end in a fraction of a second longer than it takes the pulse to travel the same distance on a wire. When the pulse reaches the end of the mercury column it can be fed back to the beginning on a wire, and the cycle thus repeated, or the pulse can be read out for use in the computer, or both.

The acoustic delay line makes the data available very rapidly—25,000 a second in the serial order that they come off the line, and at the slowest (if the machine must wait for an item to run through the column, or "tank") more than 2,500 a second. Each position of the items in the "line" of pulses in the tank is given an address, so they can be reached by the computer "instruction."

Like other high-speed memory, capacity is limited for economic reasons. One large machine can store 12,000 characters.

The line loses the data if the power is cut for a moment. However, if the memory is called upon to store data that are of lasting importance, or if a process lasts for some time, periodically a tape read-off is made of the information on the tubes or lines. Then if something causes a loss of the information on the high-speed storage mechanisms, the computation can be started up again from the point at which the tape read-off was made.

Another form of storage which makes the data available with great rapidity, but which also loses the record if the power fails, is electrostatic storage. In this system a matrix of charges is planted on the face of the television-type tube by a moving beam, analogous to that which creates a television image. Any charge can be read by the beam action, or can be rejuvenated. This system can make a "word" of information (several dozen bits) available in 3 to 8 millionths of a second. The capacity of the electrostatic storage in one computer, using 72 tubes, is about 20,000 decimal digits.

There are many other forms of storage, including barrier-grid

systems, holding beams, ceramic-coated materials, and potential systems. Many have extremely high speed—a millionth of a second being sufficient for the actual reading operation. Some highly experimental systems have stored over a billion digits in the equivalent of milk-bottle size. Work on these systems usually is top secret, and commercial applications are hard to predict.

Photographic film or paper shows promise for rapid-access memory where there is no need to erase the information. (This is possible in processes previously described.) If the data change, the variations must be stored in auxiliary storage until the main storage is re-created.

As is known from the use of photographic film for astronomy, the area affected by a light beam can be remarkably small. These devices are very compact. Methods of reading this type of storage are now under development. They show promise of enabling the storage of enormous amounts of information in a very small space; one commercial system can store data in the ratio of 90,000 to 1 as compared with printed-paper storage.

The method has already been used by the Bureau of Standards as a means of sorting items. The code number of each item is stored on film, which is scanned by a photoelectric reader.

All these systems offer at least moderate-speed "random access."

Significance of Random Access to Storage. "Random access" is a term much used in the electronic field. An easily understandable system of random access now in operation is the telephone network. When you pick up your receiver, the phone company has no knowledge of the number you are going to dial. As far as they are concerned, it is a random choice, except that you are more likely to call a number nearby; so you are more closely connected to nearby phones through the switchboards and operators.

An ideal memory would have immediate access to any data stored in it. The human brain is the nearest approach to this ideal. (The authors', however, are not good examples!) The larger the volume of data, the more it costs to make it rapidly available. Big computers have very fast access—in millionths of a second—to about 5,000 to 20,000 characters. The cost per character, however, is at present several dollars, so this machine component alone may cost over \$100,000. Using magnetic drums (see below), the computers can reach fifty to several hundred thousand items in hundredths or thousandths of a second. The cost per character will be well under a

dollar. The machines store very large volumes of data on tapes, where it may take several minutes to reach an item by running from one end of the tape to the other end, but the cost per character is almost insignificant.

The storage cells with very fast access are used to hold such items as the program of instructions, which the computer calls on in rapid succession. The systems also use high-speed storage for temporary holding of intermediate stages in calculations. The rate at which these items can be reached (the program instructions and intermediate calculations) usually is the determining factor which sets the speed of operation of the computer.

Cells with less rapid access, such as on the magnetic drums, are used to store instructions that are not being used at the moment but which may be wanted soon, as well as useful calculations—perhaps a table of functions or of withholding taxes. These may be transferred into the rapid-access memory just before they are to be used.

On the other hand, medium-size computers and special-purpose computers have only this moderately fast access to memory. It may be all they need. If they are dealing with human operators who cannot feed them information very rapidly, or if only simple calculations are required, or if the logical design of the electronic system is geared to the needs of a particular data system, moderate storage speed may suffice. In such cases, very high-speed memories are a waste of money.

Speed of random access adds considerable cost to the digital computer. If random-access speed is required for only a minor portion of the business operations, it may be best to use a moderate-speed computer plus a special system designed just to handle the specific high-speed requirements.

Magnetic Drum or Disc Storage. Where the need is for storage of a fairly large volume of data, e.g., an inventory of many thousand items which must be available rapidly and in random order, one of the best devices now in use is the rotated surface of a large cylinder or a stack of discs. The surface of the “drum” or disc is coated with the same magnetic material as is used on tapes, and the reading and writing are accomplished with the same type of “heads.” The heads may be movable or fixed.

The drums and discs are rotated at speeds which vary somewhat, but which usually produce high surface speeds—over a thousand

inches a second. Since the charges can be placed several hundred to the inch, as on tapes, the information is presented to the heads very rapidly once the surface has turned so as to bring the proper area under the reading head. This may take up to a fiftieth of a second for large drums but may be as low as one two-hundredth.

Heads may be fixed, in which case they cover a given path around the drum, or may be movable so that they can be positioned over any of several paths. The latter system is slower, taking up to a second or so to move the head. Through proper placing of the heads it is possible to have several heads reading the same channel, thus speeding up the reading. This is useful on computers which lack high-speed memories. Systems which have a movable head covering several channels are generally not used for active programs but rather for volume storage of a filing-cabinet character.

A method of increasing the volume which can be handled without greatly increasing the cost has been called "air-floating" the heads. In this type of system the heads are not fixed but can "ride" the surface of the disc or the drum on a thin film of air. Since this permits looser tolerances, a much larger surface can be used. The system has also been applied to wide tape "bands" which are, in effect, flexible drums, since they form closed loops, like a belt.

As in all types of storage, choice of the area on the drum to be read is achieved by the instruction "address." In this case, the address specifies the channel and "cell number." A special circuit and reading head count the "cells" on a marked channel. The address enables the computer first to select the proper channel and then to match the count to the proper cell where the information is to be, or has been, stored.

Magnetic drums do not lose their memory if the power is cut off. However, they may lose it if a circuit fails in such a way as to send a strong charge through the writing heads, or if a head works loose from its position a few thousandths of an inch away from the drum surface so that it gouges the surface underneath. (The same casualty may befall a magnetic tape.) Neither of the described events is likely to happen, but as a safeguard, whenever a particularly important bit of information is on the drum, it is also drawn off on a tape.

Drums of moderate size—holding 10 to 30,000 decimal digits—have been less expensive than the high-speed memory units described

earlier, and due to their advantages of random access at fair speed to large amounts of information they have been incorporated into many computer systems. The exact size of drum required must be determined from the needs of the system. First consideration is the need for the type of service that they provide. This must be balanced with the needs for higher-speed units and for more sizable slower-access units such as the tapes.

In several smaller and less expensive systems where high-speed access devices are not available, the drum is used to store the program. Drums can also be used to store some of the working data.

There are experimental drums so large that they might be used for all storage requirements. More frequently the drum is used as an intermediate storage stage, with data permanently stored on tapes. Tape reels and tape trays are also used as storage. (See "Input.")

Criteria for Selection of Storage. In selecting storage devices, the important criteria are the amount of information which can be stored, the speed with which it can be reached, and, of course, the cost of building and maintaining the system. Eckert, one of the pioneers in the field and a developer of the UNIVAC, has estimated that an increase of greater than 20 per cent in the cost for doubling the speed is usually unwise, but this opinion is not shared by all designers.

Moreover, as indicated, it is necessary to have a balance in the speed. The arithmetic system should not have to wait for the memory, if it can be avoided economically. This is the province of the computer designer, since the businessman is primarily interested in the over-all speed and cost of the system. But it is well to remember that the system must have this balance—that extra payment for extra speed in a part of the system may be wasted money.

Memory methods usually are identified by the type of medium that they employ for storage, since the various methods of using each type are fairly well known. Speeds for using a certain medium usually do not differ as much from computer to computer as do the speeds between various types of media. That is, two computers are likely to read their magnetic drums at speeds that are much more comparable than the speeds of either computer using drums compared with using punched cards or magnetic cores.

OUTPUT

Output can take two forms. One form is suitable only for further processing in the system. The other produces printed records or reports for human use.

The first form is similar to input, using tapes or cards, since in effect each such output becomes an input if it is fed back into the system. The important media for this use have already been described under "Input," and this form of "external" storage will not be considered further here.

The other form of output is of special concern to businessmen because it is often considered to be one of the bottlenecks in present systems.

Originally computers used electric typewriters for direct print-out. Some now use typical tabulating-card printers. Because the computer provides data so much more rapidly than the printers can operate, for some systems it has been thought advisable to plan for a battery of these printers. The buyer can employ the number which is economically justifiable in order to achieve the desired output.

High-speed printers operating at 600 to 800 lines a minute and more have been shown, and several firms now offer such equipment. One of the difficulties holding back the use of these printers is the problem of moving and stopping the paper at high speed. The actual printing can be done very rapidly by a number of methods. Among there are:

1. Mechanical printers (like the line-at-a-time printers now used in punched-card applications).
2. Electrical printers using special papers that can be marked by electric charges (such as the "smoke" printer), or which record characters on photographic film at high rates of speed.
3. Electronic printers that set up an image which must be photographed (like the Charactron, which sets a "pageful" of information on the face of a cathode-ray tube, from which it is photographed).

The latter two types, when perfected, perhaps will offer the highest speed of operation, over 20,000 characters a second. Some of them may prove to be the best for special applications where very

high speeds are required. However, they are expensive, and as yet have not seen sufficient use for proper evaluation of their abilities.

At present the mechanical printers appear to be most reliable and most economical. Some of these print with hammers striking rotating wheels, others with a matrix of wires which form characters by selecting dots from an array. Some of these print a line at a time, others a character at a time.

In many cases the demand for high-speed output is partly derived from a reluctance to trust tapes and drums. As these media become more and more accepted, high-speed printing will be necessary only for such items as payroll checks, customer bills, magazine addressings, invoice preparation, and so on. For these the computer can be instructed to prepare the same type of material that is now achieved with punched cards or Addressograph plates.

Emphasis on speed is frequently encouraged by the electronic engineer, who thinks in terms of printing out everything processed as rapidly as the processor provides the information. This is spoken of as a "balanced" operation between components of the computer.

However, a great deal of this print-out may be unnecessary. Reported data can be reduced through automatic analyses that are programmed in the computer, so high speeds of print-out will not always be required. For example, a material-control system may only need data on those items which were not delivered by the vendor. The computer can provide this through automatic comparison of actual receipts with promised delivery dates. The details will still be stored in the media (e.g., tape) which can be printed out in detail if necessary.

PROCESSING

Control. All large computers have an operator's panel which is used to govern the operation of the machines. The control panel usually has buttons, keys, switches, and signal lights. Using these, the operator can start and stop the machine, give instructions as to which routine to start, alter instructions in a stored program, and "communicate" with the machine. By "communicate" is meant that the operator can read the pattern of signal lights in order to tell what is happening in the machine, can stop it, add instructions if desired, and can see the effect of these instructions as portrayed through signal lights.

Since the control panel must be handled only by trained personnel, we shall not attempt to describe it in more detail. The important point is that a computer operation is not irretrievably fixed even after a program has been made up and stored in the machine. It can be stopped and the instructions changed at any time through the control panel. This is a desirable feature in any system which has to deal with occasional changes, a type of problem which cannot be handled with equal efficiency on many punched-card systems.

When a system has to be changed, however, a new program usually should be prepared and stored in the computer, for the speed of the operation is greatly hampered by human intervention. The control panel is primarily used for maintenance and checking.

Arithmetic and Logic. The logical design of the computer determines the way in which the various components are linked together, and the way in which the machine adds, subtracts, compares, and so on. The design of the computer has a marked influence on the cost, reliability, and capacity of the machine. Appendixes 1 and 2 describe the logic of a computer which uses binary arithmetic. Other arithmetic and logic are available and have been used. The design also determines the number and variety of program instructions. Some large machines have over 70 types of instructions, some scientific computers fewer than 20.

It is possible that the impact of improved logical design eventually may be greater than that of improved components. An example of the progress that has been made can be taken from the work of Floyd G. Steele. In 1948 Mr. Steele designed the Maddida digital differential analyzer, a scientific computer. The computer had 100 tubes and 1,000 diodes. Through improvements he was able to develop a new design which reduced the parts required about 75 per cent. The new design, known as the Litton-20, is much more reliable in operation and requires much less power.

While changes in designs for processing data do not reach the commercial market immediately, within the next five years the development of new components, linked by improved logical designs, will make computers and special electronic systems considerably cheaper and more reliable.

The arithmetic and logical circuits of different computers vary considerably, but all of them operate at high rates of speed. The over-all speed of most computers is not governed by these parts of the system

to any great extent, at least not to a degree that has much significance for business purposes. Speeds of operation are related more to rates of input, access to storage, and output.

In general, the user can plan to employ present electronic systems for all types of arithmetic and comparison usually found in an accounting system—to calculate payroll, bonuses, etc., to prepare variances, summaries, and so on. Many machines, and especially the general-purpose machines, can perform mathematical manipulation of far greater complexity than is ever attempted in regular business-data handling. The machines can solve differential equations, invert matrices—in a word, they open up new horizons for business analysis.

ELECTRONIC SYSTEMS AVAILABLE

There are a number of electronic systems which can be obtained for business use. Most of these are complete systems, produced by a single manufacturer. Others are made up of components from several manufacturers, although one manufacturer usually produces the major part of the system.

The specifications noted in Appendix 3 are taken from information which manufacturers have released concerning their own products. Of course, new developments appear frequently, so this material is not in any sense a catalogue. Rather, Appendix 3 should be viewed as another method of presenting what electronic systems can do—a further detailing of the material presented here.

The order of presentation in Appendix 3 has no significance. Each of the manufacturers offers equipment with abilities which make it more suitable than the others for some purposes. No one system can be best for the whole field of uses.

In evaluating the various electronic systems, the following considerations should be taken into account.

A. Speed and capacity of system, at the following points:

1. Recording.
2. Input to computer.
3. Computation and control.
4. Access to storage (volume of storage also very important):
 - a. Random.
 - b. Serial.

5. Output:

- a. In storage forms for later input.
- b. Printed material.

6. Sorting, collating.

B. Flexibility of system:

1. Ability to change its own instructions, and/or to operate from a series of stored instructions, as against use of a limited program built into the system and controlled by a keyboard.
2. Variety of instructions offered.

C. Cost:

1. Cost in terms of amount of data processed by each component in a given period, as well as over-all cost.
2. Operating costs, which include machine rental or amortization, personnel, space requirements, air-conditioning, maintenance, power, supplies. In most cases cost estimates can be obtained directly from the manufacturer.

Costs mentioned in Appendix 3 are subject to change and should only be interpreted as indicative of the size of the system.

Almost all of the equipment described is available under leasing arrangements.

Considerations other than those listed may be important in individual circumstances. Accuracy and dependability are significant, of course, but except for experimental machines, commercial equipment now rates very high in almost all instances. Since there is a constant effort to improve the machines, the degree of reliability may depend on the current state of development.

CHAPTER FOUR

Studies and Applications of Electronic Systems

Electronic computers applied to business-data processing are a development of the years since the Korean War. Deliveries of large-scale and medium-sized electronic systems in quantity began in late 1955. Estimates indicate that demand may exceed supply for some items at least until 1960. However, there have been sufficient research studies and actual applications so that businessmen now are able to learn a great deal about the selection, installation, and operation of electronic systems.

Applications of electronic computers to business-data problems already can be found in a number of functional fields such as accounting, production scheduling and control, and inventory control. Applications to special problems exist in particular industries. Hundreds of companies are actively studying the possibility of using the new electronic systems. Hundreds more have ordered electronic systems or have given "letters of intent."

Nevertheless, because of the newness of the electronic tools and because of the size of financial risks involved, a number of companies are still waiting until others have pioneered in this field. One businessman has publicly described his position with the old saying:

Be not the first by whom the new is tried,
Nor yet the last to cast the old aside.

This cautious attitude, frequently the wisest course of action for businessmen when confronted by a new field, may not be advisable in the area of electronics. Since it requires a lengthy period of study and analysis to prepare for the computer, those firms that wait too long for others to pioneer may well find themselves in a difficult competitive position.

Those who undertake this type of research find, besides other benefits from using new machines, that cost savings may be immediate. Men are stimulated to seek better systems and procedures, an outcome of the challenge presented by the result of their studies.

Enthusiasm can be overdone; some may even be experimenting with electronic devices for the pure joy of working with a new gadget. But more often the computer is regarded primarily as a useful tool, one which may help a company to face changing markets and stiffening competition.

GENERAL CHARACTERISTICS OF ELECTRONIC DATA-PROCESSING APPLICATIONS

Electronic Data-processing Systems Usually Are Selected After Feasibility Studies. Orders for computers usually have been placed only after extensive preliminary studies. The primary purpose of these studies has been to determine whether the electronic equipment was economically feasible. The studies showed that management not only would receive more timely data, but also that they would be able to release clerical help for other duties. In addition, the company would be prepared to handle more information as the volume of transactions increased in the future.

Charles E. Becker, president of the Franklin Life Insurance Company, has stated, with reference to the company's order of a UNIVAC:

Our studies revealed that this electronic system will speed many of our administrative functions to an extent which at first is difficult to grasp, while at the same time releasing valuable clerical help for other duties.

We are convinced that the insurance field in general will not be able to keep up with the continued demand for its services without introducing electronic data processing equipment to handle the heavy volume of paperwork which future expansion will bring. The physical problem of finding enough room for the employees and office equipment needed would be staggering in itself.

We have been in process of converting our procedures to electronic requirements for some time now. Four primary functions will go on the UNIVAC first: premium billing and accounting, valuation, agents' commission calculating and accounting, and dividend accounting. Others will be added as we go along.

In premium billing and accounting the UNIVAC will maintain the master file, select notices due and prepare them so that they will only have

to be placed in a window envelope for mailing, and handle the payments as they come in. In valuation the system will take care of the computation of reserve liability. All accounting necessary in the other functions will also be handled automatically.

Current plans for all four of these functions, based on present volume, will be accomplished in daily operations totaling 10 to 12 hours, five days a week—one-and-a-half shifts. The UNIVAC staff will total 20 people for both shifts. At present, this work requires 1200 clerical hours of work every day.

A special team of Franklin Life personnel is being trained to handle the UNIVAC system when it is installed in our offices. In a sense we feel like pioneers, for while this so-called electronic brain has proven itself in other applications there is no history for us to go by in our field.

We have no qualms about this, however. On the contrary, we are anxious to get the "electronic revolution" under way in our offices, for we are certain our future would be restricted without it.

In one of the first studies made, Prudential Insurance developed the following estimates of how it can cut use of office machines:

*Numbers and types of machines
used by headquarters to run its
ordinary policy service*

*Numbers and types of machines
used with the IBM 702*

21 Key punches	21 Key punches
12 Verifiers	12 Verifiers
31 Sorters	11 Interpreters
21 Collators	1 IBM Type 702
16 Reproducers	electronic data-
11 Interpreters	processing machine
16 Accounting machines	(containing about
7 Summary punches	25 smaller machines)
2 Calculators	7 Summary punches
4 Miscellaneous machines	4 Miscellaneous machines

The new system must service around 3 million accounts receivable. In so doing, each year it will send out 10 million premium notices and account for 10 million remittances. About 80,000 policies a day will receive servicing.

The system has been refined further since these early estimates. Prudential is locating an IBM 705 in each of several regional headquarters.

E. F. Cooley, associate director of methods research of the Prudential Insurance Company, has declared: "There's no shortcut in determining whether a big tape-operated system is more economical than a punched-card system." Intensive study beforehand is necessary, and even then, actual operation may alter the findings.

Gradual Conversion to Electronics Is Feasible. An example of a company which adopted the policy of gradual installation is the Metropolitan Life Insurance Company. The company examined a number of functions before it found one in which the use of an electronic computer was clearly justified. When this was found, however, and the application was coupled with uses in the other functions examined, the possibilities of an electronic computer became so attractive that the company now contemplates wide use of the UNIVAC. It is investigating the advantages of several installations.

The function which at first seemed like an obvious application was in actuarial investigations. However, study showed that, while the computer could do the work, it would not pay to have the machine for this purpose alone. The actuarial computations involved were not made frequently enough to justify the cost of an electronic system.

Another field was policy settlements, such as death claims, cash surrenders, and changes from one plan to another. In policy settlements there is need for frequent reference to tables of unit cash values, tables of single premiums, etc. While it was possible to program a computer to calculate the proper values, the volume of this work alone was too small to support a computer, especially since the computer would require storage capacity that was quite large compared to the use value of the information.

File keeping on magnetic tapes was also examined. Policy information could be kept on tapes, but on investigation it was found that no machine existed with sufficient random access for this type of storage.

The area which provided the largest clerical savings was regular policy service. The policyholder must be notified when the premium is due, the amount of premium, and the amount of his dividend. The computations involved, while simple, are in large volume. The system must provide regular notices and statements to the policyholder. However, it became clear that in order to use an electronic computer effectively in this area, very extensive changes would be necessary. The company wanted to acquire firsthand operating experience before

any far-reaching changes were made; therefore it looked elsewhere.

It found the area of work it was seeking in its actuarial division. A large amount of routine repetitive work is done there to develop the actuarial statistics needed for the company's financial statements and for various analyses of its experience. Investigation disclosed that it could gainfully apply an electronic computer to this work, so the company arranged for the UNIVAC to do the job. Thus, the task of producing actuarial statistics, which involves large volume but little computation, was found to be more productive than actuarial investigations and its related computing requirements.

The company regards this area as a particularly good one. It was localized to one division. It involved a minimum of changes before the company could get started. No policyholder service would be impaired if the operation failed. Since the work for which the electronic computer substituted was already highly mechanized, it required the computer to establish its superiority over punched-card techniques rather than over clerical procedures—a much more difficult thing for it to do. The annual rental of machines initially replaced was over \$200,000.

Because Metropolitan Life operates on a highly centralized basis, with much of its work concentrated in one location, the large volume of work necessary to justify an electronic computer was readily available. Smaller companies, and those whose activities are more widely separated, may not be as fortunately situated.

Metropolitan Life chose an application for first installation where difficulties or delays incurred in the process of installation or early trial runs did not affect the normal operation of the business. The company was able to train its employees in computer technique. Actuarial work requires the use of capable actuaries, who made the transition to computers more easily than nontechnically trained people. Once experience was gained on this application, others of a nature more concerned with temporal deadlines and with personal relationships were introduced.

The experiences of the Metropolitan Life Insurance Company have been repeated in other companies. They have found that the electronic computer can justify itself economically on simple repetitive routines that are not complicated but voluminous.

There exist certain problems in insurance applications which require special consideration and which illustrate the necessity for a

careful study of all the side effects of an adoption of electronic processing systems. For example, there is some question as to whether information recorded electronically will be acceptable to the various state courts and insurance departments. Only recently have some states accepted printed copies of the annual financial statement for insurance companies. Some courts still will not accept microfilm records. The company may need a visual record of the policyholder's account, which the computer will have to print out.

For other applications, such as filing, company officials have expressed some worry about the fact that a machine cannot exercise judgment if there is an error. For example, if a number on the policy is slightly incorrect, or a John Smith is recorded as John Smythe, the machine cannot look up plausible alternatives and find the data as easily at present as can a human clerk.

More than One Function Will Be Handled by the System. Almost all companies that have ordered large-scale general-purpose computers expect that eventually they will put more than one function on their machines.

George Troost, vice-president of Chrysler, has aptly summed up this attitude:

We believe it is necessary to develop an integrated approach wherein the requirements of sales, procurement planning, material control, production, statistical, accounting and Treasury functions are viewed together so that a consolidated and coordinated system of data processing can be thoroughly developed.

The concept of integration lies at the heart of one of the most comprehensive programs undertaken by any company in this field to date—the “common-language” project of United States Steel. Description of various aspects of this system is given in other parts of this book. It has also appeared in a variety of other publications, such as those of the American Management Association.

Another company which has a comprehensive program is Sylvania Electric. Early in 1954 Sylvania established a team under the supervision of the controller. Its assignment was to make an evaluation of every piece of equipment available, or likely to be, and of every installation which could be visited.

The basic philosophy adopted was that the company should establish a data-processing and communication center. The location was

to be chosen solely on the basis of the communication needs of the company, the available communication systems of A.T.&T. and Western Union, and desirability as a place where the company could get the necessary personnel to be willing to work. It was not to be influenced by any particular production location, but to serve several dozen factories in all sections of the country (with the possible exception of the West Coast).

The communication center was to serve the needs of decentralized management, not to centralize the authority-responsibility relationships of the company. These needs were believed to be characterized by one dominant factor: In recent years competitive conditions have compelled management to continually shorten the time period between events and the receipt of information concerning the events.

The company installed a UNIVAC in 1955. It was estimated that it might take 2 years at best for the installation to pay for itself, but in the last analysis this was not the vital factor. They were aiming to get next-morning reports on:

1. Exact inventory, by location.
2. All sales.
3. Production.

If the machine could aid in stopping "dog runs"—production of unneeded items—then the saving would be far greater than any anticipated from clerical functions.

Don Mitchell, president of Sylvania, has declared that the advent of electronics will "separate the men from the boys" in management. In the past, too often a manager could put off a decision with the excuse that he had to have time to gather more information. Now, everyone will know that he can gather the information rapidly, and it will be up to him to make decisions when they are called for.

Pacific Mutual, one of the first to install a computer, came to the conclusion that they could not justify the use of a large-scale machine unless they placed more than one function on it. Some of the functions would have to accept changed routines. For example, to answer certain types of inquiries it now would be necessary to wait until the next morning, since the material would be stored on tapes. It is not economical to run some of these more than once a day.

A related aspect of the Pacific Mutual installation is of considerable interest. At the time the company installed its UNIVAC,

in the fall of 1955, the new UNIVAC II, featuring use of magnetic-core memory, had become available. Nevertheless the company decided to continue with the first UNIVAC, at least for the time being.

The first UNIVAC uses acoustic delay lines for high-speed memory. Magnetic cores are faster and somewhat more reliable. However, they cost more. Pacific Mutual decided that though the acoustic delay line was technologically obsolete, it was not economically inferior. It would provide all the speed of computation which they required. If more high-speed storage should become necessary as use of the computer increased, the memory could be converted.

Incidentally, Pacific Mutual hired an expert for full-time assignment to the task of answering the numerous inquiries about their installation.

Transition to Electronics Is a Time-consuming Process. Detailed installation studies often require 12 to 18 months for one application. The first application generally takes the longest. Personnel must be retrained to program a computer or else new people skilled in programming must be hired and trained according to the company's requirements.

General Electric's application study for payroll at the Louisville plant began in September, 1953, and the first electronic payroll was run late in 1954. Six months later substantial improvements in the program were still being installed.

Four procedures analysts and two outside consultants made up the first group. The work was divided into the following categories:

1. Day work and individual incentive.
2. Group incentive.
3. Computation of gross pay, premiums, and other items, for both hourly and salaried workers. Distribution of labor cost and maintenance of employee files were included.
4. Computation of net pay, including all taxes and other deductions.
5. A general study, which covered the reports that were required, desirable changes in number codes, etc.

The initial group was expanded several times. The exact size of the working force is difficult to assess, since the project was used to some extent to train analysts and programmers for the company and for outside consultants.

Since major responsibility remained with operating divisions, it

was necessary to form committees to keep them informed and to give them a voice in the design of the system. This gave the computer group a chance to educate the other men in the workings of an electronic system and helped reduce opposition to the change.

Controls were developed at the point where documents originated. The purpose was to ensure that all documents were received in the data-processing center, and also that all information received was processed by the computer. Documents were batched, given a control number, and the time and identification were logged.

After the materials went through key punch (which was necessary for input), the cards were balanced against a control card on an accounting machine. The control clerk then checked the total with the payroll section to make sure all the data forwarded were received.

Cards were then converted to tape. A tape-control total was prepared and checked against the card control. The first computer run was to sort the data; during this run totals were prepared to balance the data on the tape against the control total.

The extent to which such controls are required cannot be established without study of a particular operation. Because of the nature of an electronic system, introduction of faulty data is often quite costly, so that fairly elaborate control of input is often justified. Establishment of such systems takes time.

Electronic Systems Require Detailed Descriptions of Methods and Procedures. Because computers are not "brains," they must be given detailed instructions in order to carry out their function. Companies that already have good methods and procedures will have some advantage. However, very few companies have found that their systems and procedures are sufficiently detailed for electronic requirements. Illustrations of this will be given later in this chapter.

General Conclusions concerning Installation Studies. The following general conclusions have been reached by a number of companies that have pioneered in electronic systems:

1. Over-all predesign of the program should be as complete as possible before the detail-flow charting and coding are undertaken. Changes tend to "cascade," like dominoes.
2. A computer can handle all sorts of exceptions, but unless these recur with some frequency it is uneconomical to program and code for them.

3. Sorting the information so as to report it in various sequences is usually an expensive process. (Development of better sorting abilities or larger internal storage may relieve this problem.)
4. Correction of errors should be designed to be handled as part of the system. Otherwise reruns, and sometimes reprogramming, may be required. The errors should be located as early as possible to prevent compounding.
5. Programs must be tested thoroughly before they can be used without difficulty.
6. Achievement of pay-off in complicated accounting routines is not an easy task.
7. Coordination between members of the study group must be of a very high order. Their efforts must be integrated.

The remainder of the chapter is devoted to a more detailed description of studies and applications in particular functional areas.

APPLICATIONS IN ACCOUNTING

Accounting applications include payroll, billing and accounts receivable, disbursements and accounts payable, and cost accounting. However, in studying these applications, it always must be remembered that there is no hard and fast line between the different types, such as between payroll and certain phases of cost accounting. Nor is there a line between "accounting" applications and "inventory" applications. The distinctions are made here primarily to achieve a useful grouping of examples in the presentation.

Payroll. Payroll computation has been a favorite choice for a number of companies. The expense of present procedures, plus the fact that in many cases these are already mechanized, has led many experts to believe that payroll should be one of the first to be placed on the computer.

Experience, while limited, has shown that payroll can be handled electronically and that the systems can be made economical. However, the many considerations involved in any fairly complicated payroll make it appear unlikely that substantial savings can be realized in this area soon after the installation is made. A careful study of the system is an absolute necessity, and this is both time-consuming and expensive.

Such firms as General Electric, U.S. Steel, and Ford have favored payroll as the first application for their actual or potential business-data processing system. There are several reasons why payroll may be chosen in spite of the risk indicated. Payroll, as a system, is more or less complete within itself. The volume of items is large. Current clerical costs are substantial. There are many computations, and great accuracy is required. There are elements of the data which must be stored, changed frequently, and reported out rapidly. Payroll is frequently handled now by IBM CPC's, or 604's, which are electronic computers of an intermediate character.

Payroll data are used for a variety of reports, each report embodying somewhat different classifications of the same basic data, and each of which must be prepared regularly. This type of multiple-purpose processing is one of the electronic computer's best applications.

Cost Studies. One study showed that a company with about 15,000 employees and a weekly payroll spends approximately \$545,000 a year for payroll and for processing of labor reports. Of this, about \$240,000 was for rental of punched-card equipment, almost as much again was spent for tabulating personnel, and another \$75,000 was for divisional clerical costs to re-sort the tab reports for various management uses. It was estimated that an electronic computer could do the same work for a rental of about \$250,000 a year, plus about \$120,000 for labor costs, thus netting a saving of about \$175,000 a year.

The present payroll and labor distribution system takes about 10 days, while only 3 days would be required by the computer. Since this would enable the computer to be used for other applications, the company estimated that they might save as much as another \$500,000 a year. Even after discounting this somewhat, because of possible overenthusiasm, there is a margin of savings sufficient to warrant computer installation.

A recent study undertaken by another large company disclosed that it could justify the purchase of a computer for its payroll alone. The computer could prepare the payroll, involving 140,000 to 150,000 men, in about $3\frac{1}{2}$ hours per day (about 85 hours of computer time a month). In this connection it should be noted that most of the computers now in use are on a 24-hour-a-day schedule, with only a few hours down time for maintenance and repair. With sequence programming only a few people need be present to handle the actual operation of the machine on late shifts.

In assessing these estimates, it also should be remembered that the experience of most installations has been that time approximations were overly optimistic. This holds for both programming time and operating time.

The above studies assumed continuation of the same methods of recording workers' time on timecards. Not much experimentation has been reported in this field, and there is some question as to when it will pay to replace this part of the system. Eventually, however, the timecard no doubt can be eliminated by using another form of input, such as paper tape or magnetic tape produced directly by the time clock. Or the information could be sent by direct wire from the clock to a central computer where the processing could take place immediately.

Test Runs. Because of the importance of accuracy for payroll, it has been considered advisable to test-run the two systems in parallel—the old system in use, and the new electronic system. Such a procedure helps to get the defects out of the system before the switch-over is made. One study estimated that a complete change from first study to final change-over should take about 1 year. (Other studies have shown a year to be somewhat long.) Of this time, approximately 3 months was to be spent on program testing and on making several experimental runs. In general, studies show that at least 6 months should be scheduled to program, code, and test the electronic payroll procedure.

Because of this preparation, the cost of installing the computer is generally equal to the cost of the computer. As more experience is gained in this change-over, it seems reasonable to expect the time will be reduced, but the cost will continue to be substantial.

There are a number of reasons why such a lengthy period of time is necessary. One difficulty arises from the fact that most systems in existence for payroll have been developed in line with various operational functions and not as one integrated payroll system. As a result, before the payroll can be programmed on the computer, it is necessary to make a detailed system study and to integrate the various payroll procedures. This type of study requires the cooperation of engineers or programmers who know the attributes of the electronic machines, but who seldom know much accounting. Since most accountants know only parts of their payroll systems, and few of them have learned the attributes of a computer, such a systems study obviously takes time.

Once a study has been made, programming and coding the payroll system for a computer take additional time. The programmer should take into account many of the various exceptions which are handled manually at present, outside the mechanical system, since the ability to handle these is one of the advantages of a computer. A high level of competence is required to be able to work these exceptions into a system. The integration must be complete, for the computer must be told exactly what to do with any of the exceptions it handles. A testing period to correct the program and codes and to provide for any oversights has proved to be necessary for all such complicated types of applications.

Application Experiences. In the General Electric installation at Louisville it was originally estimated that a complicated incentive system for about 8,000 men could be handled by the computer in a few hours a week. This proved to be an underestimate.

It required over 20 man-years to prepare and code the GE program. Even after several months of operation there still were difficulties with some items. The original program for the computer, including exceptional payroll situations such as special deductions, required over 200,000 instructions. To run such a program required about a full shift for a week. Some exceptional situations were determined to be inefficiently handled by the computer using the extended program, and were again given individual clerical handling. This change together with improvements in the program has reduced running time considerably.

Part of the computing problem at General Electric was due to the fact that there were three major methods by which hourly rated employees were paid: day work, piecework, and group incentive. Any one man might conceivably work on all three during a given week.

The General Electric approach was to devise a system by which the computer would be used to compute the payrolls and write the checks, leaving the responsibility for the remainder of the functions still with the various departments. This attitude was strongly influenced by the fact that the computer was to serve five decentralized departments. Therefore it was decided not to establish a central payroll section built around the computer. How much this influenced the success of the installation is difficult to determine.

An important by-product of any intensive system study is the improvement which can be achieved in basic methods and procedures. This may go a long way toward covering the expense caused by the

necessity for lengthy study. Subsequent applications, as well as the necessary changes that will occur in the payroll system, eventually should be handled with greater speed and less expense as a result of the improvements that can be made in the computer itself and in the methods of staking out and attacking the problem.

An example of the results achieved by an intensive system analysis is National Tube, of U.S. Steel. Although the company had spent a number of years in establishing the same basic labor-accounting system in each of its plants, various local modifications had been permitted. These were not significant as long as punched cards were used. When the electronic system was introduced, the payroll system had to be restandardized. Otherwise the programs for the computer would have been unwieldy, or reruns of the data would be required.

An important result of such a study is the number of desirable items, not susceptible to mechanization on punched cards, which become simple by-products of properly designed computer runs. Examples:

1. Determination of vacation and holiday eligibility. These are based upon average earnings during a reference period.
2. Analyses of absenteeism, tardiness, overtime, etc.
3. Reviews of stewardship. National Tube calls this "quota control."
4. Automatic denomination of payrolls paid in cash.

General Conclusions on Payroll. Once the data are available for machine use and suitable programs have been developed, pay checks can be printed, and payroll ledgers and reports that are prepared concerning payroll can be made up automatically. Changes in parts of the report requirements can be given the machine without changing the other parts of the program.

In considering the desirability of using an electronic system for payroll, it should be remembered that a primary benefit of the computer is its use for related applications, such as labor-cost distribution, and labor reporting of statistics such as turnover, status of employees assigned to a given department versus the authorized number, and so on. Data for all of these can be accumulated simultaneously, thus increasing the speed of preparation considerably. Some initial studies made in a company with well over 10,000 workers and several hundred products showed that the computer could prepare detailed labor reports in somewhat over three hours.

Once the basic data have been recorded on a tape, the computer has considerable flexibility as to the type of report which it presents. Installation of a new report will require careful study, with a time period of as much as 1 to 3 months. But when the report programs are ready and available, the computer can gather the data for a number of reports simultaneously, and can switch from the preparation of one report to the preparation of another automatically and much more rapidly than is possible with card systems.

Since payroll preparation must meet a fixed deadline, reliability is a major consideration. Computers do not have a long history of reliability, like that of punched-card machines. A computer can do many things, but it does place a lot of "eggs in one basket." Therefore most payroll studies include consideration of the desirability for the computer to have stand-by facilities in case of breakdown. This stand-by may be another computer some distance away, since the tapes, etc., can be flown great distances overnight, and the payroll checks can be similarly returned.

Concern over breakdown has been minimized by the testing and modular developments which have been described previously. As for the speed of output, although high-speed printers are desirable, the same result can be achieved through use of several slower printers. In some cases the tapes can be converted to cards and a typical card printer employed.

Receivables and Payables. There are numerous studies under way which are concerned with the application of electronic systems to receivables and payables. It has been found that, although study of other companies' experience can be informative, no application can be adopted by another firm without change. For each application there must be detailed investigation of the individual situation. The basic elements are fairly similar in many applications, but the specific types of information needed, the different points of origination of data, etc., must be established precisely.

A study now under way at a leading oil company concerns the problem of handling sales of gasoline on credit cards. The company processes by hand several million slips of paper a month. A large amount of clerical work is involved in sorting the slips that come in at various times and from various stations. The company is experimenting with a method which would record the slip on film for the company's permanent record. This would be followed by addition of metallic spots

in a coded arrangement, automatic sorting, then billing to customers, and totaling sales for each station.

Because this company's policy is to have the sales slip returned to the customer with the bill that is mailed to him, it is necessary that the original paper evidence be sorted also. Oil companies have found that a typical customer does not remember all his purchases and may doubt the total billed to him without the signed sales slips. The problem, of course, has been to find a simple and inexpensive method of doing this. Several companies have experimented with procedures that mark the slips of paper so that they can be read and sorted, then processed for billing.

A more direct system, known as Scandex, has been developed to read original evidences photoelectrically. A tabulating card, similar to those now used for this purpose, is prepared at the point of sale. The card is imprinted with data from the customer credit-card identification.

When delivered to the data-processing center, a photoelectric reader scans the information, verifies the account number, then automatically key-punches the scanned data into the original invoice. An adding machine can key-punch the dollar amount of the sale.

Estimates show that equipment renting for \$1,000 a month (including service and maintenance), should show a gross saving of about \$1,000 a month per million invoices. The system can be applied to situations where point-of-sale data can be controlled, such as with customer identification by credit plate as used by department stores.

Applications—Utility Billing Procedures. The large volume of customer billing required by public utilities obviously offers a major opportunity for cost saving and improved handling in the utility industry. A number of different studies have been made of the potential use of electronic systems in public-utility applications. First installations are currently under way.

Complete information concerning each customer's accounts can be kept in a main file. Each account shows the customer's name and address; the identification of all meters on the premises; the revenue class and the business code for statistical analyses; the last reading of each meter; consumption and demand figures for the last few months for each meter (for commercial accounts the amount that the customer *might* demand is a factor in calculating the bill); the gross amount of the bill; the net amount; the due date and the amount of any bills

not paid; the current balance of the account; the description and amount of any miscellaneous charges or merchandise charges; the amount of the deposit, if any; and notations for credit actions, if any, taken in the past.

In a computer system the accounts will be processed in order, by account number. The number, for example, may be a code developed from the reading day, the section of the city, route, block, premises, and individual customer. The tapes can be kept separate for each reading day, so that a partial sorting would thus be achieved. If the readings come in the same order as on the tape record, the sorting is facilitated.

One pass through the tape input will be sufficient to put the new data from the meter readings into each account, while at the same time the consumption is calculated, a meter constant multiplier is applied, and the consumption is compared with past consumption to see if it is reasonable in the light of past experience (this would tend to catch reading and transcription errors). Where necessary, the readings for several meters can be added to determine consumption and adjustments can be made for periods greater or less than the scheduled billing period and for readings that indicate the consumption for more than one family unit.

If a reading is missing, the machine can calculate and average for the immediate past period and make up a bill. Meter readings which appear to be out of line can be automatically segregated and listed for later investigation.

As the changes and payments are entered into the main file, a program of selection can be watching for all items of unusual nature which should be treated immediately, such as bills past due or service disconnect ordered but not performed. These data can be drawn off and printed separately. Records for accounts requiring off-schedule final billing are also drawn off. Payments recorded to the wrong account are noted in a separate list. Information necessary for the preparation of new meter-reading sheets is made up by the computer, which can print them out when desired.

Receivables—Commonwealth Edison. One of the most advanced computer applications for billing is at Commonwealth Edison, in Chicago. W. E. Eggleston, machine procedures accountant, began his investigation of electronic possibilities in 1949, before any electronic machines were available or even certain to become so.

Commonwealth Edison serves 1,800,000 electric utility customers in

the Chicago area. They have scheduled the meter reading and billing on a bimonthly basis. The typical monthly bill for a residential town is under six dollars, so the billing and record keeping per dollar of gross income are important cost factors.

The company had developed a highly mechanized system for customer billing. Meter readings were recorded on mark-sense cards. Bills were computed by IBM 604's. The meter card became the receivable ledger record. The returned stub, which was prepunched, was processed mechanically, including the reduction of the receivable ledger. Any remaining ledger cards were added to the next meter card to produce the new bill. In this punched-card system only two points required clerical handling in detail—meter reading and acceptance of payment.

After careful studies it appeared doubtful that a large electronic computer system could compete with an efficient punched-card system if it was restricted to the functions just described. It was necessary therefore to enlarge the computer application to include the "exceptions."

In a punched-card system, it is necessary to maintain a large clerical force to handle these "exceptions": separate files for advance deposits, separate records of collection on slow-moving accounts, and adverse credit information. Inquiries about accounts by customers who have lost their bills are so frequent as to be a major factor in building the accounts-receivable system.

The effort to build an economic system to handle these "exceptional" items has taken several years. At one point it was estimated that to print out all the information that conceivably might be called for each day would require an acre of printers, working double shifts. Or to have all the information immediately available on drums instead of tapes would call for a yearly rental of some \$300,000,000!

Preparation for the electronic system made it necessary for Commonwealth Edison to reexamine its detailed procedure. The solution adopted was to use tape records instead of cards for customer data. The tapes contain the name and address, metering and rate information, details of money due, and credit and collection standing. Basic customer tapes are reproduced three times a month on a cycle basis to spread the work load. The new tapes are used to print out an open-balance list which omits much of the fixed data but is sufficient for most of the required account reference.

During the interval until the next basic tape is made up and the new open-balance list printed, a compact auxiliary list is prepared. This is printed daily. This auxiliary list shows charges or credits which have occurred since the open-balance list was printed. The daily auxiliary list is cumulative. A customer inquiry can be answered by referring both to the open-balance list and to the auxiliary list. The latter constitutes about 10 per cent of all printing.

This is a method for handling a file economically where a great quantity of information is involved if most items change infrequently. It is also being applied in many other types of installation. Telephone directories, certain inventories, stockholder lists, basic employee data, and many other types of lists are susceptible to this method of reducing the print-out and/or file-maintenance requirements.

A bill register is prepared every time bills are issued. This contains everything that is on the basic record tape. Since changes occur to the "fixed" data, such as the customer address, a record-change list also is made up. This list is coded to refer to a daily record of register changes. When a particular item is consulted, either the bill register is correct or the changes can be traced quickly through the record-change indicator.

Commonwealth Edison took delivery of an IBM 702 in the summer of 1955. They also had on order an IBM 705 for delivery in the summer of 1956, and a second 705 a half year later. The first 705 was to replace the 702, the second to do general accounting.

The programming group for the billing on the 702 installation was composed of five men from a public accounting firm, four from IBM, three from the Peoples Gas Light and Coke, and sixteen from Commonwealth Edison. The latter were men who had averaged 24 years of service with the utility. The billing program required over 30 man-years to prepare. This does not include the time required for training.

It was originally planned to take over a year to place the entire group of 1,800,000 accounts on the computer. An experimental group of less than 50,000 accounts was run first in duplicate to test out the electronic systems program. Once the "bugs" were worked out on the experimental group, conversion of the remaining accounts proceeded at an accelerating pace.

Telephone Billing. Automatic Message Accounting is the name of a system used by the Bell Telephone companies. Also known as AMA, this system automatically records and processes on continuous paper

tapes all data required for presenting charges on customer-dialed calls.

Many telephone rate plans include "message-unit billing" for messages to nearby points. Using the proper factor, relating the place called and the conversation time, this equipment computes the charge for each such message. These charges are then sorted and accumulated to provide a total message charge for each account.

Where greater billing detail is required, the AMA system produces a record of each message, including such data as called telephone number, date, and time. These records may be either printed slips or punched cards, depending upon the type of subsequent accounting treatment selected to transform the AMA record into a customer's toll statement. This highly specialized telephone-message accounting system is notable for self-checking features which preclude overbilling.

When you pick up your telephone and dial, a piece of equipment called a recorder perforates into a tape your telephone number, trunk number, and a message-unit rating code (in the case of a message-unit call), or the called telephone number (in the case of a toll call). After completing this entry the recorder is then free to record calls originating from other customers. As soon as you receive an answer to your call the recorder is called in again. The answer time and trunk number are perforated. The machine is then free to continue recording other calls. When you hang up, the recorder is called in for a third time. It perforates the disconnect time.

At 3:00 A.M. each recorder perforates a special pattern which will allow the tape to be cut. The tape is then forwarded to the accounting department for processing in one of their Automatic Message Accounting centers.

The accounting department splices the tapes together for each central office and then runs them through a series of five machines: the assembler, the computer, the sorter, the summarizer, and the printer. First, the assembler brings together the three elements of the call—the telephone number, the answer time, and the disconnect time. The computer computes the elapsed minutes of the call and converts the sum into message units for message-unit calls. The sorter sorts the messages into calling-telephone-number sequence. The summarizer adds the total message units used during the month for each telephone. Finally, the printer prints a list, intelligible to anyone, listing the telephone number and the total message units used during the month. It prints a slip containing details for toll messages.

Instead of using the printer, tapes for those central offices served by a revenue accounting office with punched-card message-unit or toll-billing procedures may be processed by a tape-to-card converter. This machine produces a punched card for each telephone number, representing the total message units used during the month, and a card for each toll message.

The output of the AMA center is then forwarded to the revenue accounting offices, where the message units are combined with message units for operator-ticketed calls and calls recorded by message registers. The message-unit allowance is then deducted, the charge and tax computed, and the result entered on the customer's bill. Toll messages must be rated in terms of money, recorded for intercompany settlement purposes, and entered on the toll statement. In cases where the revenue accounting office has punched-card equipment, the AMA output may be in the form of a card, and certain of the revenue accounting operations are performed mechanically.

Company studies have indicated the need for extensive analysis of all the various influences on the billing and receivable data processing. If, after a program has been prepared, too many exceptions must be inserted in the computer manually, then the benefits to be expected from rapid electronic processing may not be realized.

General and Cost Accounting. A number of studies of electronic systems have come to the conclusion that there will be a substantial use of the systems in the fields of general accounting and of cost accounting. Among the characteristics which make this seem likely are the large volume of data handled in most accounting systems, the availability of cost standards according to fixed patterns, and the usefulness of the information if it can be prepared rapidly.

Perhaps the most ambitious of the general-accounting approaches is that of du Pont, which is testing both a UNIVAC and an IBM 705 on a tentative lease basis. The du Pont organization is studying the following computer applications (not listed in order of importance):

1. Cost accounting. Production and cost records are required for 80 plants. Two were selected for initial study.
2. Payroll. Three plants and the needs of the 35,000 home office and other home employees were analyzed in initial studies.
3. Production scheduling.
4. Billing and sales.

5. Personnel records.
6. Property records.
7. Accounts payable.
8. Stockholder lists.
9. Technical and scientific calculation.

Du Pont studies began separately in several different functions. They were brought together under a steering committee in 1953. The first order for a computer was placed in 1954. The installation studies were expected to take at least two years.

An installation group at Chesapeake and Ohio has been studying the possibilities of using electronics since 1952. They advocate what they call "a one-shot process." Using input from waybills, passing reports, wheel reports, interchange reports, car orders, rates and divisions, payroll data, materials requisitions, reorder levels, purchase orders and receipts, etc., they plan to produce as output:

1. Timely digested results for management decisions and action.
2. Exceptions for investigation.
3. Detailed listings for reference.

A company chart, used to explain this concept, says specifically, "The emphasis is on integrating the whole."

In order to prepare for the data-processing system, C.&O. found it necessary to make careful studies of company needs and also to establish a faster and more comprehensive communication system than the company already had. Both efforts yielded dividends even before the electronic installation. Methods research developed an application of statistical sampling to short-cut certain clerical procedures. Their work also has led to design of a new communication system, using teletypewriters and emphasizing improved use of the waybill. Company spokesmen have characterized this improvement as "able to stand on its own feet in a highly competitive situation."

An interesting example of an attempt to integrate an electronic system to provide for various accounting needs is the study made by Blue Shield. This study determined the way in which the RCA BIZMAC system could be used to handle enrollments and claims for the group medical plan.

Three main programs were studied, each involving a different set of master tapes.

The purpose of the first computer run was to update and correct the

enrollment master tape, to record separately the data removed from the enrollment master, and to compare the claims on a transaction tape with the enrollment master in order to separate those claims where the two disagreed as to certain data.

The second run was to correct the experience master tape, to separate claims being processed into:

1. Those having no prior related claims.
2. Those having prior related claims.
3. Rejected claims.

Consecutive check numbers are assigned to those claims having no prior related claims.

The third run was to update the doctor master tape, to prepare a tape for preparation of checks, and to prepare a tape for claim statistics.

The BIZMAC system features flexibility in sorting, conversion, and print-out, which gives it some advantages for this type of problem.

Consolidated Edison, New York, has contracted for rental of two UNIVACS, and an IBM 705, for delivery in 1956. Two machines will be used on customer accounting and the third on general accounting. The decision to employ both types of equipment was made after a study of company requirements which took over a year.

The company expects to process 1,500,000 customer accounts monthly, weekly payrolls for 23,000 employees, 9,000 other payrolls, 100,000 inventory items of storeroom nature, and 9,000,000 property-account items.

Monsanto Chemical has made a number of experimental cost analyses, using an IBM 701 and 702. They have reported that the results are encouraging, and that a program of further investigation, leading to use of later models for general accounting purposes, has been undertaken.

Because of the size, intricacy, and importance of general and cost accounting systems, these applications have not been favored as one of the first for electronic computers. They probably cannot be handled economically by special-purpose systems. Extensive use of computers for accounting applications has had to wait for the introduction of more general-purpose data-processing systems.

Among the uses which have been judged to be well adapted to the abilities of general-purpose electronic systems are the storage of

standard cost information and automatic comparison with actuals to produce variance reports, the statistical analysis of variances to highlight only those which are worth executive attention, the development of data for cost estimates for bids and pricing through rapid assembly of individual costs stored in the system, and the development of costs for inventory and cost-of-sales reporting.

Special-purpose Accounting System—Bank Checks. An example of a special-purpose electronic system for accounting purposes is the ERMA (Electronic Recording Machine, Accounting). This machine was sponsored by the Bank of America and developed by Stanford Research Institute.

ERMA credits individual accounts with deposits and debits withdrawals. It maintains a record of all transactions and keeps a correct balance. It stores stop payments and hold orders and prevents overdrawing of accounts. It also sorts the checks.

The machine has five input keyboards, each resembling a large adding machine. Different sets of keys are provided to represent the account number, the branch number, and the amount of check or deposit.

Entries can be made at an average rate of about half a second. Switching between the entry keyboards is automatic, so that if several entries are made simultaneously, the machine will accept them all and only require a wait of about a second for the operator.

The computer employs two large magnetic drums, providing storage sufficient for 32,000 accounts.

Checks are precoded with magnetic ink, so that in the typical entry the only data that need be supplied by the operator is the amount of the check. The other information is placed on the back of the check as a set of magnetic marks. The name of the customer is also printed on the front of the check, so that a comparison may be made with the signature to be sure the customer is using the checkbook issued to him.

The magnetic marks can be read at the rate of 1,000 characters a second. Dirt, ink, or other defacements do not interfere. The checks can be sorted at the rate of 10 a second. During test runs, errors were less than 1 in 100,000.

In a typical entry, the operator depresses keys to indicate the amount of the check and the fact that it is a withdrawal. The machine scans the back of the check and automatically depresses the

keys on the entire identification number. If the coding is not present, the operator can supply the number.

The remainder of the operation is automatic. The machine obtains the current balance from the drum. It also scans the drum for possible stop payments or holds. It subtracts holds from the balance before processing the check or notifies the operator of stop payment. Otherwise it merely subtracts the amount of the check and stores the information, including the new balance, back on the drum.

The machine automatically sorts the daily activities and enters them on a master tape, once a day. On this tape the full record of all account activity is stored in serial order. From this tape the monthly customer statements are prepared, as well as other information for management.

The first ERMA was placed in operation in San Jose, California. The Bank of America contemplates use of 37 other machines at other branches.

The research cost has been estimated as of the order of several million dollars. Neither the Bank of America nor Stanford Research plans to manufacture the equipment; rather it is expected that a major portion of the cost can be recovered by sale of the patents. It is expected that the machines can be produced in quantity to sell somewhere in the neighborhood of \$200,000 to \$300,000. At such a cost they will provide a saving over present practice, while relieving personnel of a tedious task.

Summary—Accounting. The studies and installations discussed indicate the following advantages of electronic systems when applied to accounting:

1. The computer does not have to replace the whole present accounting system to reduce costs and be effective.
2. In many cases some change is required in preparation of the source documents.
3. The present group of skilled accountants and systems personnel often can be utilized after some training.
4. It has been found that where a routine requires a large volume of either clerical or machine data processing, potential savings are sufficient to justify acquisition of a computer. Additional savings are then available from other applications.
5. Computers are sufficiently reliable to be trusted with accounting

routines which require a high degree of accuracy and dependability.

6. Future savings can be achieved through anticipating potential uses of a computer, in current studies regularly made of accounting systems and procedures.

However, there are still some problems to be considered.

1. Integration of the detail in accounting systems requires a substantial period of time. There is a lack of personnel who can relate the accounting and electronic requirements.
2. There is a serious risk of upsetting the accounting system. An installation must proceed cautiously, be checked and double checked at every point, both as to the electronic computer's program and as to the accounting system itself.
3. There are internal and external limitations on the use of computers for accounting purposes. There are legal restrictions as to the type of record required for regulatory purposes and for admissibility as evidence in court. Original documents must still be retained for audit and tax reasons.
4. To realize the savings may require the displacement of people. Resistance may be encountered from management as well as from unions.

INVENTORY AND SALES

Generally speaking, present inventory applications have been developed by using the smaller electronic systems. By "smaller" is meant the computer systems in the hundred thousand dollar class, or less, as opposed to the million dollar machines. The latter do include inventory work among the operations they can perform. Moreover, they can tie it into the complete data-processing system. So far, however, this has not been accomplished extensively.

There are several types of application which do not require that the handling and processing of inventory data be related directly with other accounting. Special electronic systems have been developed for these inventory applications. These systems record such information as incoming orders, or the status of a few thousand items of inventory. The cost has varied from thirty thousand to a quarter of a million dollars for the first models.

The savings which have been achieved with these smaller computers, or specialized systems, have been sufficient to justify a number of installations. As a result, more special systems were installed for this purpose than for any other type of business information system, until general purpose computers began to be produced in quantity.

In most branches of the retailing industry frequent physical inventory counts have been required. It has not been economical to keep perpetual inventory records, using present accounting systems. Therefore certain types of information, useful for management decisions, had to be provided by special groups of clerks.

Experience has shown that these inventory information requirements could be supplied by special electronic systems.

Careful studies had to be made before the machines were built. It has been particularly difficult to anticipate all future requirements. In the best systems as much flexibility has been built into the equipment as could be achieved economically.

Application—John Plain. An operating example of an inventory system is the Speed Tally at John Plain.

John Plain, a wholesale mail-order firm, distributes gifts and home-ware to thousands of customers. Not counting sizes and colors, they carry about 8,000 items in inventory. The business is highly seasonal; daily orders can vary from 2,000 to 15,000, with an average of 10 items per order. However, the majority of the orders are for one or two items. Most of their business comes in the fall quarter.

Mr. Lachman, chairman of the board, initiated an investigation of electronics to solve John Plain's unit-inventory requirements.

Mr. Richter, president, has stated:

Filling orders promptly is the most important part of our business. Delays and omissions are costly for us and disappointing to our customers. To ship promptly, we need balanced inventories. To keep inventories balanced, we need fresh, live information. This is especially true at the height of the season, when some items sell rapidly for a few weeks and then lie dormant until next year. . . .

Our old system of keeping tally on incoming orders was acceptable, until a few years ago. We used the time-honored method of tallying incoming orders by check marks, in 5's on prearranged sheets. When our business grew to the point where it took 40 clerks to tally and 20 more to accumulate the tallies, the system began to creak. Even with 60 operators, we were able to supply only weekly reports to our buyers. They

wanted daily reports! To give them that would have required a staff of 150 tally clerks.

A firm of consultants was hired. They recommended that the problem be studied with the Engineering Research Associates (now a subsidiary of Remington Rand, a division of Sperry-Rand). The electronic system built as a result of this study was called the Distributon by John Plain. Speed Tally is the name given to it by Remington Rand.

The Distributon now requires only seven girls at most to keep a record of incoming orders. This compares with about 60 previously. Yet more information is available, more rapidly.

The Distribution was given a fixed program. This enables John Plain to use a simple adding-machine type of keyboard as an input-and-control device. It requires a minimum of training of operators. When the operator depresses the keys for the quantity ordered and the item code number, the machine follows the program. It automatically calculates and records the new total.

Nonexistent item code numbers are rejected automatically. A light flashes to indicate a mistake. If the operator punches a wrong item number she can correct the error.

The program is set to enter automatically a quantity of one, the most frequent order size, merely by depressing the keys for the item code number. This saves the operator time and effort. The operators, as a group, can enter information into the system at an average rate of less than a half second per item. The machine takes information from one keyboard at a time. The other keyboards, which may have received a complete entry, are locked for a moment. Then their information is automatically accepted. In practice it was found that operators could prepare information faster than was expected, so that seven operators kept the "allotter" at capacity, although ten operators were originally planned to be used.

Another part of the program enables any operator to read out, on a board, the total for any item at any time. This permits the operators to answer telephone requests by buyers for information on specific items. The total for any or all items can be printed out on adding-machine tape at the rate of 75 a minute. The items can be printed in any desired order. The order is controlled by a punched-paper tape.

The machine has a number of features which give it some flexibility.

It is designed to utilize transistors when they become economical. The drum can hold 39,000 items. This gives it sufficient capacity to keep up with the growth of the firm. Or it can be used to store several kinds of information at the same time.

The machine was not designed to provide accounting information, although the drum is a standard model and might be incorporated in a larger electronic system. It does not order or bill. This still is done by the buyer and the accounting department.

After less than a year of operation, the John Plain tabulating group found that they could improve the operation of the machine by modifying the input keyboards so as to prevent the central unit from receiving certain types of erroneous entries. A check bit was added for each catalogue number to assure accurate transfer of information from one area to another on the drum. Another important change was to cover all relay chassis in the equipment so as to prevent dust from being a source of maintenance problems.

Quoting Mr. Richter:

. . . we find that it [the Distributon] has several accomplishments to its credit. With 10 operators [now seven] it does quite easily what would have required 150 tally clerks. It eliminated an employment problem, permitted us to engage more highly skilled operators, and saved much needed office space. More important, it has helped us to keep inventories balanced, with the consequent reductions of omissions and leftovers. But, best of all, we are giving top service to our customers. Some of these gains can be measured in dollars . . . but we believe that the dollars saved are outweighed by the intangibles.

The Distributon was built to suit the particular needs of the John Plain Company. The success of this machine does not mean that it is suitable for other companies. For example, another mail-order company, Sears, Roebuck and Company, has studied the system.

John Plain was fortunate in that its code was fairly complete. Sears, Roebuck employs a combination of numbers, letters, and description. This may impose problems of recoding the catalogue for machine purposes.

Application—Department Stores. A less successful application of a special-purpose system was attempted by a large department store. After the machine was installed on the sales floor to provide unit inventory data, it was discovered that the capacity of the memory was

insufficient for the data requirements. The machine had 14 digits available for each item, but the company soon found in practice that it needed at least 26 digits. Among other factors, additional digits were sought to provide the buyers with dollar information.

The machine was an experimental model and not fully tested. As a consequence it had a number of operating failures. The manufacturer has estimated that it spent about \$10,000 for special repair and maintenance on a machine that cost about \$30,000 to build. (The machine was originally sold to the department store for considerably less than it ultimately cost to build and maintain.)

The department store has estimated that the machine saves the time of two clerks, which would have provided adequate pay-out at the store's original cost. But this saving would not be sufficient to justify an expenditure of over \$30,000. This demonstrates the need for careful planning and cost estimation.

A number of other department stores are experimenting with special-purpose electronic systems. Altman's in New York has used a Magne-file with a storage capacity of 63 digits for each item. The machine can process data for about 8,000 items of furniture.

The first 21 digits were used to identify 400 manufacturers and 100 item classifications.

The other 42 digits were devoted to seven groups of information, with six digits available for each:

1. Dollars on order, at cost price.
2. Dollars received in month, at cost price.
3. Dollars received in month, at retail.
4. Dollars in stock, at retail.
5. Dollars sold for the period, at retail.
6. Dollar returns for the period, at retail.
7. Dollar markdowns for the period.

Rich's in Atlanta is studying methods to control inventory. For this type of installation, one study has shown the following to be desirable:

1. Number of items on order, per each item.
2. Number in stock, per each item.
3. Number sold for the period, per each item.
4. Minimum reorder point, per each item.

In addition the system should be designed to group totals for many different classifications, to give sales figures, sales per salesperson, and totals on taxes, discounts, and salesmen's commissions. Separate totals show what amount of the sales were cash or charge, take or send.

Rich's is actively investigating various electronic devices, and is co-operating with computer research at Georgia Tech for this purpose.

Associated Merchandising Corporation, a federation of department stores, has a program of research in electronics. The general reaction expressed so far has been that the experiments have been worth the expense and show considerable promise.

While special-purpose electronic systems show promise for dollar and unit control of inventory in department stores, there also have been a few studies of the application of general-purpose computers to this field. The advantage of a general-purpose computer is that it would permit integration of inventory information with ordering, billing, and other parts of the accounting system. Recognition of the need for an integrated system has long been recognized in the department-store field. A project known as Central Records was started at Kaufman's Department Store in Pittsburgh, about 1929. This system used pre-punched card inputs, one of which was given to the customer, one put on each piece of merchandise, and one given the salesperson.

In the experimental runs all three tags were placed in the machine, which printed out the customer's name in the Central Records office. A clerk looked up the customer's credit and then pressed a button which signaled the selling floor so that the sale could be completed. There were standard card punches in the Central Records office, which took the information from the three cards in the transmitter, plus that from a cashier if cash was involved. When the transaction was recorded, the transmitter opened and released the cards.

If the customer had lost her card, the information could be supplied by keyboard at the transmitter. Part of the merchandise card was given the customer as a receipt, and the customer signed a book kept beside the transmitter to recognize the sale. The punched cards could then be used for merchandise control, sales audit, and accounts-receivable posting.

The system worked well enough for Kaufman executives to order further development, but machinery that could give satisfactory per-

formance never was developed and delivered. Eventually the project was dropped.

The Central Records concepts are currently being revived.

Point-of-sales Recording. Sears, Roebuck has been experimenting with a punched-card system developed by Kimball and Potter Instrument. Under this system the inventory items are given a small, split-tag type of card. Part of the card can be detached and used to initiate the accounting process. At first some difficulty was experienced in achieving accuracy in reading the tag. Tags became shopworn, bent, etc. The systems have gradually been improved, and installations have now been made by a number of stores.

Reading is done photoelectrically or mechanically. Information is usually transferred to a standard punched card, from which it is used in the normal way for various inventory and other purposes, but it could be given directly to the computer. The Kimball Company has withdrawn from the project to concentrate on other aspects of the computer field. Remington Rand has undertaken to develop this further with a machine called the Tag-omatic.

A number of department stores, such as Macy's, and Robinson's in Los Angeles, are experimenting with point-of-sale recorders—systems of recording sales information at the selling desk. Telecomputing Corporation and National Cash Register Company have devised methods for preparing computer input as the sale is recorded. Early models used punched-paper tape, prepared at each register and then transported to computer input stations.

A British concern, Rentrax Ltd., has developed a direct system, linking the cash registers, processor, and a "consulting unit" in the central office. The transfer of information can be made over distances by telephone wire.

The cash registers can be fitted with keys to give as many categories of information as desired. The data are read out on a lighted screen at the central office, where the desired categories can be selected at will.

Dennison Manufacturing Company has a print-punch marking machine which simultaneously records on price and inventory tickets all data that can be known about a unit of merchandise prior to sale. This is done by punching holes in the cards. Supplementary data, type of sale, salesperson number, price at which actually sold, etc., can be recorded at moment of sale. All data for each transaction can

be recorded on a tape. This may be teletyped to a home office for automatic processing.

Airlines Reservisor. A special type of inventory problem is found in the transportation field. Space allocation is required for many forms of passenger operation. Reservations are made by ticket agents at scattered geographic locations. To obtain maximum loading it is desirable to provide the agents with information concerning current space availability for particular trips. It is advantageous to have this information while the prospective customer is still at the ticket-selling location.

In 1952 American Airlines and the Teleregister Corporation introduced a special electronic system called the Magnetrone Reservisor. An input device is located at each reservation desk and at each of the major ticket-selling locations. The devices are connected by wire with a central computer located in New York City. Because of the speed of the system it can serve over 100 input locations.

At each station the operator has a set of metal plates which have various indentations. The plates operate as a precoded programming device. Each plate represents a different flight or series of flights. The operator places the plate for the chosen flight in a slot in the input mechanism and depresses buttons for the number of seats desired and the date.

A magnetic drum is used by the computer to store the number of spaces available for each flight. As the input requests are made, the computer automatically selects the proper flight and compares the sum of the old and new reservations with the total number available. If there are more seats available than requested, the computer sends back signals to the input device, which indicates that the reservation can be accepted by illuminating appropriate lamps.

If the customer decides to take the space, the operator starts over. She flips a key on the input device, which automatically subtracts the number of seats reserved from the old total and stores the remaining inventory of available seats in the machine. A cancellation can be handled by the input device by adding to the total of reservations available.

If the customer wishes to know the first flight which will be available to a certain destination, the operator can obtain this information. The whole operation takes only a fraction of a minute. If two stations try to reach the computer at the same time, only one will be connected.

The other station will not receive an answering signal until the other has completed its entry. Experience has shown that such delays are not significant.

The Reservisor has sufficient capacity for 1,000 daily flights, 10 days in advance.

A desirable feature of any special-purpose system is that it should be capable of taking on additional duties. The American Airlines system is a good example. In the spring of 1955 the input devices and the central mechanism were altered so as to give information on expected time of arrival of current flights. By pressing an added set of keys, but using the same plates to identify the flight, the operator can learn if the plane is on time, or how late it is, according to one of several time categories.

The pay-out time is difficult to determine because of the intangible advantages. For clerical savings only it has been estimated as being as much as five years. The system has been in use for several years, 22 hours a day, and has operated about 99.8 per cent of its scheduled time.

United Airlines has installed a Reservisor system, and several railroads have installation programs.

Stock Quotations. An interesting variation of this inventory technique, also developed by Teleregister Corporation, is the Toronto Stock Exchange Bid-Asked Register. This is a magnetic-drum machine which makes prices available to 200 dial request subscribers, at a rate up to $4\frac{1}{2}$ requests per second.

Prices telephoned by reporters on the Toronto Stock Exchange trading floor are entered by keyboard operators and transmitted to Teleregister display boards above each trading post. The prices also appear on a large board before the operators, to enable them to check accuracy.

A drum provides for storage of 2,000 sets of prices. (Six hundred was the initial usage.)

To request a quotation, a broker dials a three-digit number. At the central office in the Exchange building this number is decoded, partially by the older Teleregister equipment, and finally by the new electronic equipment. The desired stock is automatically located on the drum. A mechanical transmitter sends the prices out. The answer, including stock number and prices, appears on a ticker tape at the requesting station.

Combining Special- and General-purpose Machines. The problem of relating special systems (such as file maintenance, or inventory-count machines) to general-purpose computers has been explored in a number of studies. Some firms require a large volume of memory only for certain parts of their operations. A satisfactory solution may be to have a special-purpose and a medium-sized general-purpose computer. Large-scale general-purpose equipment may not be economical. Rapid selection of data regarding any one of a large number of items is expensive in most general-purpose computers, so this would be handled by the special-purpose equipment. The less extensive operations then could be put on a medium-sized computer.

On the other hand, companies which purchase special-purpose equipment to satisfy special needs are confronted by a serious problem. The advantages of their special electronic data-processing equipment often may be made obsolete by changes or improvements in the company's information flow. Changes in business procedures also may render obsolete the special-purpose equipment.

In order to avoid such obsolescence, the electronic equipment manufacturer is faced with the problem of designing some flexibility into his special equipment, or he may persuade the user to make a special study of requirements in order to convert existing procedures to ones which are likely to persist and which the equipment can handle economically. The business user is then faced with the difficult task of evaluating changed operating methods and of deciding whether they would result in a saving.

If electronic equipment is sufficiently flexible, an installation can be made evolutionary rather than revolutionary. The equipment can be adapted to a company's procedures, both as they now exist and after they are changed. General-purpose computers provide this programming flexibility. They can be adapted to many (but not all) procedural changes. They also permit more than one function in the organization to use the equipment. On the other hand, increase in flexibility usually increases cost.

To gain the advantages of both types of systems some electronic manufacturers, as well as some individual companies, are developing special-purpose computers which can enter inventory information, make preliminary calculations, do preliminary summarizing and sorting, and make elementary decisions. The general-purpose computer would receive from the special computer only that information which

is necessary to post the inventory accounts for general accounting purposes.

Mail-order System. This "combination" approach is of particular interest in connection with problems like those of the Spiegel Corporation. Spiegel has circulated a detailed technical description of its operations with the request that electronic manufacturers suggest possible systems.

In a typical mail-order house incoming orders are processed through item tally, then cash analyzing or credit, as appropriate. Then they proceed to a ticket-pulling operation. Tickets, preprinted with appropriate information, such as price, weight, and description of the item, are available by catalogue number in racks. A clerk processes a given customer order by selecting the appropriate ticket for each catalogue number on the order.

The tickets are then manually marked for color, size, catalogue by which purchased, and quantity. Mailing labels are prepared. The orders are scheduled and stamped with a packer number. This schedules the people who will wrap the orders for mailing.

The tickets are then separated from the customer orders, sorted by the various merchandise departments, and dispatched. At each department they are tallied by size, color, and catalogue number, flagged if out of stock, then released for stock pulling. Each merchandise item is placed, together with its pull ticket, on a conveyor-belt system for transportation to the wrappers.

Customer orders are separately routed to the packer. The packer number determines the time and the packer station which is to receive the merchandise and order. The complete order is merged and packed at a packing station. It is then weighed, stamped, the customer is billed, and the merchandise is shipped.

Data gathered at the tally stations serve to prepare management reports on stock conditions, sales by items, sales by catalogue, etc.

Receiving and transfer information is routed to the tally stations to correct their inventory figure. The same data also are used to prepare reports on purchases, receivals, and shortages.

The tally operation often proves troublesome. Especially during seasonal rushes it induces error into the system. Studies have shown that file-maintenance equipment, as described previously, can help.

Following this it is planned to automatize many of the clerical operations. For example, the ticket-pulling and preadjusting functions

can be replaced by electric typewriters directly connected to a special-purpose inventory computer. A typewritten form replaces the pull ticket. As the clerk who receives the order types the catalogue number, the data is accepted by the special computer, which refers to its memory, looking up description, weight, price, and other information. These it sends back to be typed automatically on the form. The computer also checks available inventory and the total of requests for the item. If stock is available, the machine indicates that the item can be sold. It then adjusts the inventory and the tally of orders. Canceled orders are maintained in the same manner. If the item is out of stock, the computer indicates this. At the same time it keeps a tally of orders for out-of-stock items for buyer information.

The special-purpose computer also prints out invoices and other associated documents for completing the order. Such a special-purpose computer also would be designed so that managers could determine the status of any item at a moment's notice.

Periodically, the contents of memory can be transferred to a magnetic tape, in an ordered form. When combined with other information, this tape can be used by a general-purpose computer to produce management reports, postings to the accounting records, etc.

By using both special-purpose and general-purpose computers the sorting problem is minimized, especially if data are collected in a preset fixed order. In some systems separate tapes could be produced for each requirement, at the same time, by the general-purpose computer. Each tape then could be transferred to a printer, in any sequence.

Large-scale Inventory System—Air Force Supply. The Air Force has under development an extensive inventory-control system. The first installation is an IBM 702 at the Oklahoma City depot.

The system is designed to keep a complete central-inventory record by processing all transfers to the system, plus those between the depots and bases and between the bases and the unit supplies. All requisitions would create a punched card, which could be transferred over the new IBM Transceiver system. The Air Force has leased lines 24 hours a day to build up a communications network for this purpose.

A major study project is under way to evaluate the four large-scale commercial computers—the UNIVAC series, the IBM 700 series, the BIZMAC, and the RAYCOM. It is expected that eventually several

dozen of these large-scale general-purpose machines will be utilized for this purpose.

One of the advantages of the system is to permit the Air Force to keep larger supplies near the operating level. Better control would facilitate interbase transfers of scarce items in a manner not now possible. Also it would enable the system to build some flexibility into reorder points and standard order amounts. These could be made to depend upon the quantity of an item available in the over-all system.

Summary—Inventory and Sales Applications: The studies and installations discussed, concerning inventory and sales applications, indicate the following advantages of electronic systems:

1. Special electronic systems are economical for some inventory and sales problems.
2. To obtain economical advantages it is necessary to integrate the data information needs and the design of the electronic system. The results of this integration have been simplified input, sufficient machine capacity, and special features which reduce operating costs.
3. Inventory needs can be combined with production, purchasing, and accounting requirements through the use of special-purpose and general-purpose electronic computers.
4. It is possible to utilize input-output devices, at decentralized locations, that are directly linked to a central computer.

However, the following should also be considered in the application of electronic systems to inventory and sales:

1. A special system developed for a particular application in one company may not be usable by another company in the same way. A single different factor may be sufficient to make it uneconomical.
2. Special electronic systems still have limitations. The amount of rapid random-access storage that can be obtained at reasonable cost is not large enough for many applications. (Manufacturers are working hard to improve this.)
3. Obsolescence of special-purpose equipment is also a serious consideration.

PRODUCTION CONTROL AND SCHEDULING

During the years after World War II it has become increasingly apparent to management that methods of production control and scheduling need improvement. Developments in production control and scheduling have taken two directions—mechanization and introduction of new techniques.

Some companies have moved toward mechanization by using punched-card machines. Such applications often strain the ability of the equipment. Many manual operations are still required. Use of punched cards is limited by the amount of information that can be processed economically. Also, it is difficult to put in sequence certain operations on punched-card machines.

A number of applications are contemplated which relate linear programming and other new developments with production control and production scheduling. Current research in these areas has indicated that production control and production scheduling are different types of problems. Each requires a different approach. Solution of production-control problems requires the use of mathematical techniques which maximize profits, taking into consideration such factors as the current forecast of sales, the available resources of the company, the operation costs, and the state of technology. The solution provides a program which sets forth the best product mix for a given period.

Scheduling, on the other hand, is the detailed guidance of operations in conformance with the program. The schedule sets forth the times when materials, parts, labor, and machines are to be made available to specific operating units; the amounts of each resource to be provided; and the expected results. Somewhat different mathematical techniques are useful.

However, both production control and production scheduling can benefit from the use of high-speed computing equipment.

There have been few actual applications of electronic computers to production control and scheduling. Extensive work is being done by research groups in the larger corporations, and it is generally believed that the area of production control and scheduling is one of the most promising for applications of electronic computers. A large volume of computations is required. There is need for faster preparation of schedules in order to achieve better control of material, labor, and machine utilization. Clerical handling of data is expensive.

A computer can do the necessary work efficiently and economically. Moreover, the computing need not be done at the plant. Several companies have declared that they intend to place a computer in a central location to serve all of their operating plants. Others, however, are decentralizing such work; many have ordered a medium-sized computer for each plant.

Recent research indicates that better mathematical methods for production control and scheduling may soon be available. Dr. A. Vazsonyi has formulated mathematically a method for determining parts requirements. Work on mathematical techniques to solve production problems is also being done at the RAND Corporation, UCLA, Carnegie Tech, and by the Cowles Commission at Yale University.

A number of companies are making scientific studies of production control and scheduling. Among these are General Electric, Lockheed, Ramo-Wooldridge, Thompson Products, Ordnance Supply of the United States Army, SKF Industries, Standard Oil of New Jersey, Hughes Aircraft Company, International Business Machines Corporation, and Litton Industries. In most cases these companies plan to use computers to perform the necessary computations and to prepare the paper work.

Application—Lockheed. A group working at Lockheed has prepared full sets of production orders on an IBM 701 computer. They have turned out, in a few hours of computer time, aircraft orders which otherwise took more than a week to prepare. The manager of production scheduling has stated that use of the computer has not caused the discharge of a single man and is not likely to do so. He has emphasized also that use of the computer has enabled Lockheed to produce more realistic schedules and programs, which result in lower cost of production.

Lockheed has found that the higher speed of the IBM 701 and 704 scientific series is so desirable for their production needs that it offsets other advantages of the IBM 702 and 705 business series. Production scheduling requires a fair amount of calculations. The company has contracted for several 704's, but also ordered a 705 for general accounting purposes.

Lockheed managers hope to use their computers to help them analyze the problem of production acceleration. The company went through two periods of rapid acceleration—during World War II and during the Korean conflict. Partly because of scheduling difficul-

ties, the company sometimes experienced increasing costs as the number of planes built increased, rather than achieving a reduction in cost per unit, as should be expected. The managers plan to analyze past data, taking into account the labor market, skills required, rate of pay within the community, availability of space, housing and transportation, as well as a host of in-plant factors. By use of multiple correlation techniques they believe that factors can be developed for use in future programming and scheduling of production. The factors can be combined into "hours per pound," and used to estimate the time required to build airplanes. Use of a computer also facilitates continuous reexamination of the factors used for the estimates as production proceeds.

Underwood Study. The Electronic Computer Division of Underwood has examined the production-control system of the company's Hartford works. The Hartford plant produces typewriters. The study was made to determine which parts of the production-scheduling system could be handled economically by the Elecom 125.

The proposed electronic data-processing system was designed to continue use of all the source documents currently used. As experience was gained with the computer, various record forms could be dropped, particularly as the production-control personnel gained confidence in the computer. It was extremely dangerous to change old flows of documents without careful investigation, because the documents might be needed for purposes other than those immediately evident.

The problem of change-over to a new electronic system was examined in detail. It was concluded that the change-over could be accomplished either at one time or piecemeal.

A comparison between the present system and the one using the Elecom 125 is shown in the table on page 90.

Underwood expected to save the time of these people while using the computer only 4 hours per day. The extra machine time could be used on other applications, such as payroll. In addition to savings in clerical costs, the company felt sure that human errors in the present system would be minimized by use of more highly trained personnel. All entries would be made twice and checked by one of several alternative methods. Mathematical errors would be held to a minimum.

The system would prepare the operating reports. A daily production report would be provided, one which compared the actual production

Function	Present system		New system	
	How often prepared	Number of personnel	How often prepared	Number of personnel
1. Master schedule, kept up to date every day.....	Daily	12	Daily	2
2. Stores and ordering record..	Daily	6	Daily	2
3. Special-parts schedule.....	Daily	6	Daily	2
4. Production-manufacturing schedule	Once every 2 weeks	12	Every 2 weeks	2
5. Material-allotment summary	Once every 3 months	7	Once every 3 months	3

to that on the master schedule. A control report would be prepared daily to show the parts-inventory status of those items which were in a plus or minus balance. Feedback of information would be provided only for those items which required management attention.

Other Studies. Systems for production control and scheduling can be usefully interrelated with the data processing for accounting, inventory, sales purchasing, management control, and other parts of the business system. It seems evident that a general-purpose computer will be desirable for most installations. In order for an electronic system to be able to handle a variety of operating problems or varying methods of data analysis, it must be flexible. To achieve this flexibility in a computer with a built-in-program is likely to be so expensive that the user might as well obtain a general-purpose computer. However, file-maintenance computers may have applications in scheduling, for inventory control and for priority choice.

An example of the complex interrelationships which exist between production control and the other areas mentioned is found in the experience of the Bureau of Aeronautics.

The Bureau of Aeronautics has used a CRC 107 for production scheduling of government-furnished equipment to meet production schedules of aircraft manufacturers. The scheduling requires the monthly quantities of items needed. It involves adjusting schedules to provide installation lead times to meet airframe company requirements. Adjustments to monthly requirements are needed because

of changes in types and quantities of aircraft and equipment. Changes occur daily; at time of initial studies they averaged about fifty a week. Schedules are completely reviewed each month.

One of the problems encountered by the Bureau was the lack of understanding between the person familiar with the problem and the person programming it. This difficulty will be a common one for similar applications in the future. One reason for this difficulty was that the individuals presenting a problem have been so misinformed as to what computers will do that they do not present their problem in sequence, in simple terms, and in complete detail. As a result, the programmer had to go to several persons to gather the entire information. Of course, in many cases it is nearly impossible for any one person to present the problem in its entirety. Some problems are too far-reaching in scope, and too many people are involved.

There is a feeling among some production people working in job shops that the production-control problem probably is too difficult for an electronic machine or system to handle. They suggest that electronics may be useful only in production control of standard large-lot process-type industries, like an automobile assembly plant. However, some research workers believe that pay-off in production control eventually will be found in any situations where present manual or punched-card methods are taxed to capacity.

Production Control—Study of Job Shop. An in-plant study of production control was undertaken by the Management Sciences Research Project at the University of California, Los Angeles. It was sponsored by the Logistics Branch, Office of Naval Research. The study was headed by Richard Canning.

The plant studied was a large job shop in the local area. It employs about 1,000 persons and supplies complex metal assemblies to the aircraft industry.

The production-control manager had tested various methods to control the flow of work through the machine shop, including punched-card systems and modern adaptations of the Gantt-chart technique. He had chosen a relatively efficient manual system based upon the use of control boards in each fabricating department.

The major problem confronting the production-control manager is to estimate the work load on each machine-tool section a few days in advance. Since there is no standard routing, jobs can and do flow into a machine-tool section from all the other sections. Bottlenecks

develop overnight. When such bottlenecks occur, considerable expediting action is required. Since bottlenecks cannot be predicted, life in this plant is a continual process of expediting for production management.

The proposed electronic system records the present location of all orders within the plant. It can compare this location with the scheduled location and select for management action those orders which fall behind schedule more than a specified amount.

The requirements for parts can be determined by the machine. Parts shortages can be detected for expediting action.

Intermediate start dates can be computed from information concerning the present location, priorities, and the flow times for future operations. For expediting action estimated due dates can be compared with desired due dates.

In addition to control functions, the proposed system can perform much of the clerical paper work. The maintenance of perpetual inventory records for each part number, maintenance of customer order information, issuing of shop orders and purchase orders, and many other functions are within the scope of the system.

A special-purpose scheduling computer to be loaded from the shop-order-status tape was suggested. The computer starts working its way into the future, hour by hour. When a machine tool is shown to be available, the scheduling computer scans through all waiting shop orders and picks the one with the highest priority that is slated to go on that type of machine tool. At any desired time, the computer can stop and total up the number of shop orders waiting in each department. This gives a picture of scheduled hours versus available hours.

A control board is used to present a picture of the progress of critical shop orders. A route sheet overlay is placed on the board. Lights indicate the position of the shop orders. As the scheduling computer works its way into the future, the lights "step across" the control board. At the same time, a display panel indicates the "hypothetical future date."

Should one of the critical shop orders not make satisfactory progress, or should a future bottleneck become apparent, the chief expeditor has several choices for corrective action. He can change priorities to move some jobs faster. He can schedule overtime work, or he can send certain jobs outside. By manipulating in this way, he can

derive a satisfactory schedule for the next week or two. Also, he can get a rough idea of the future by letting the computer run out a month or two in advance.

A rough estimate of the time scale for this operation is 15 minutes of electronic computer time per 40 hours of shop time.

The system designed was only of a preliminary nature. The purpose was to see if it was economical and to set a pattern for subsequent research. Later, however, several companies in the Los Angeles area used a similar approach for studies of their requirements for electronic equipment to handle production control.

Summary—Production Control and Scheduling. It is generally recognized that the area of production control and scheduling offers many opportunities for the use of electronic data-processing equipment. Nevertheless, the problems are complex. Some experts believe that new devices are required. Others feel that the problems must be formulated in mathematical terms, using new techniques of analysis.

In general, it is expected that successful applications will require the talents of a team of experts who can design or appraise new equipment, who understand production-scheduling problems in detail, and who can apply new methods to achieve solutions.

DOCUMENT HANDLING

In addition to the use of electronic systems for business-data processing, there has been a considerable amount of effort directed toward solution of the problem of handling documents.

Regardless of the efficiency which electronic communication may achieve, paper documents will continue to be used for many purposes, at least in the foreseeable future. The sorting and delivery of paper records and authorizations is one of the most costly of certain types of clerical operations.

An example is the volume of checks which must be processed by banks. Several banking groups, and individual banks, such as the Bank of America, have been actively investigating this field. They have sponsored the development of print readers and of methods of coding by attaching metallic dots or magnetizable strips to the documents.

The major problem is to achieve initial recognition of the identifying and quantitative information on the document. Once that is done, sorting, accumulating totals, and transferring of the document can be

done automatically. For further processing, the information can be placed on media suitable for use in computers.

Development of the necessary equipment has reached a stage where commercial installations are feasible.

SUMMARY

Applications of electronic computers have now been made to a number of different data-processing functions. The degree of initial success has varied. Substantial savings in time and in clerical effort have resulted. Cost savings, however, have been more difficult to achieve. It is believed that in many cases the economic benefits will come from the ability to perform more service at practically no increase in costs, rather than to cut costs dramatically by performing the same operations electronically.

Study of various types of installations shows that there are certain aspects which are unique to each installation and a few which most systems seem to hold in common. The specific ways and times at which information is required for planning and operating are peculiar to each situation and must be studied in detail. These needs, together with different physical circumstances at points where events occur and are recorded, result in specific requirements for input devices, and to a lesser extent for special processing and output equipment.

Similarities exist which enable one to group applications in several general categories. Some applications, usually of a scientific or engineering type, require moderate input and output but large amounts of computation. Some, like payroll, require voluminous input and output and in addition require that records for almost every "item" (e.g., employee) be changed at each processing. Others, like inventory control, require voluminous input and output, relatively little computation, and reference only to a fraction of the items in the master file in any one processing run. The latter case is sometimes called a "low collation ratio."

Each type of situation calls for a different type of electronic system. The first is usually called a "scientific computer." The second—such as for payroll—is the "general-purpose computer." The third, and in some respects the latest to be developed, is the "file computer."

Finally, there are some aspects that seem fairly general. Of these, the most important is the basic concept of the flow of data through

typical electronic systems. Very frequently this flow is an elaboration of Figure 4, which is a highly condensed "flow chart."

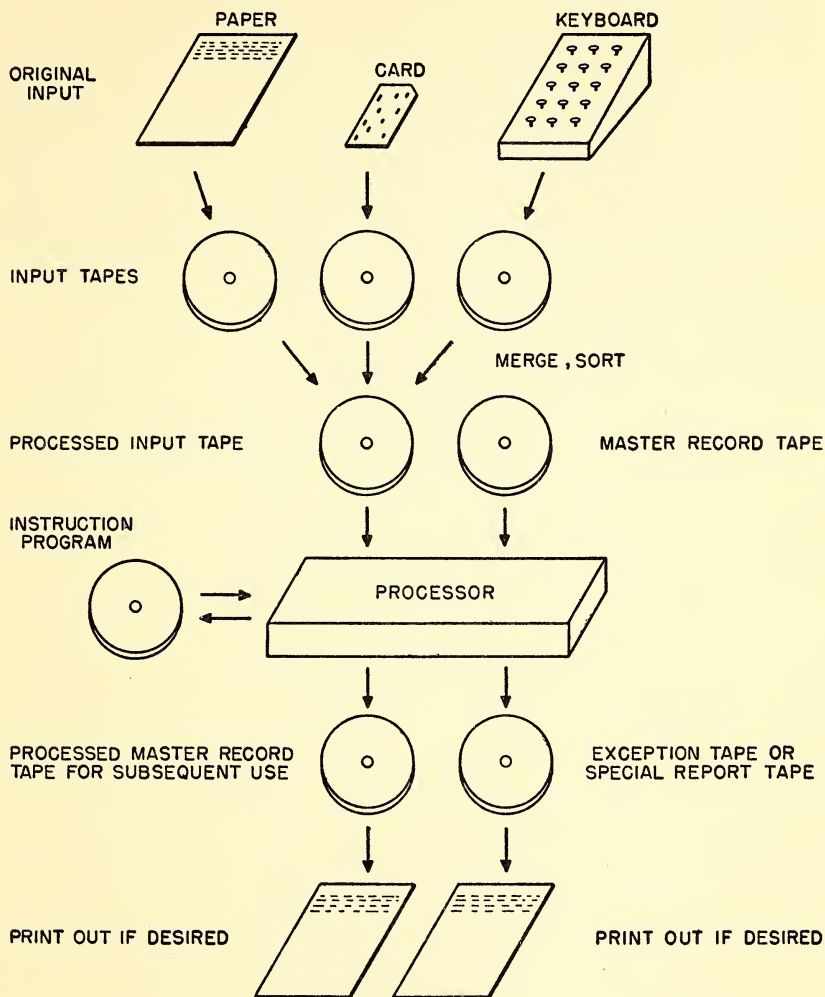


FIGURE 4

Some of these steps may be omitted—the input may go directly from the keyboard to the processor, or sorting may not be necessary. On the other hand, the system may be greatly elaborated—there may be a number of reports prepared simultaneously by the processor. However, the general pattern is already evident in many types of application.

In virtually all cases company experience has encouraged executives to expand their efforts in this field. There is a general belief that in large and many medium-sized companies electronic data processing eventually will dominate record keeping, communication, and provision of managerial information.

Experience has also shown that achievement of the results which are ultimately possible will not come easily. The administrative problems will be tremendous during the period of adoption of the new systems. New methods of system analysis, emphasizing the scientific approach to business problems, will have to be employed if the electronic machines are to operate with maximum effectiveness. In the longer range, an entirely new and different approach to management planning and control is indicated. And, ultimately, automation of the office will be coordinated with automation of the factory and with the use of the computer as a tool for scientific research if the full benefits of electronics in business are to be achieved.

CHAPTER FIVE

Administrative Problems Experienced in Introducing Computer Systems

The introduction of an electronic system creates a number of administrative problems. Old equipment must be replaced in an orderly manner. People must be retrained, regrouped, or relieved. Various kinds of experts may have to be hired, familiarized with the company's problems, and fitted into the organization. Data-gathering, -processing, and -reporting methods will have to be revised.

Coordination of the change in machines, men, and methods will require a high order of administrative ability, based upon an understanding of the interrelationship of various aspects of management planning and control, electronic systems, and integrated information systems.

General Electric's Installation. There are no installations as yet which can serve as models for a solution of all these problems. The General Electric Company has been the first in America to experiment with the installation of a large-scale general-purpose business computer. Their experience is being watched in the hope that it will eventually provide answers to many of these problems.

The General Electric Company built a plant at Louisville, Kentucky, to relocate and replace the facilities for the production of five major household appliances. This modernization and geographical centralization of certain lines gave the company an opportunity to experiment with and to develop newer methods of production and of data processing. In a new operation, there is less concern about replacement of machines, retraining of personnel, and introduction of new systems. Executive attitudes, therefore, favored investigation of automation and electronic data-processing systems.

Approval of the directors was secured for a study of electronic systems. Of course, authorization of capital expenditures for an actual installation was contingent on the results of the study.

In companies where the support of top management has not been obtained, groups investigating the feasibility of computers have been hampered in defining problems which should be investigated. The investigations have been restricted to the functional areas under control of those who take responsibility for the study. As a result, although some of the studies have shown that an electronic system can be used for a particular application, it could not be shown that it was the best application, or even that it was feasible from the over-all company point of view.

For example, in one company the controller found an application to cost accounting which would reduce the clerical costs substantially. He had his staff group make a detailed analysis of the way the computer should be used. Meanwhile, with the approval of management, the production department was engaged in an automation program to reduce manufacturing costs. The system the production group proposed would, in their opinion, make most of the data handling unnecessary. Months after the two studies had started the overlap was finally recognized. By then both groups had strong vested interests in their own programs. As too often happens, a choice between the competing interests was made in a political environment.

The General Electric Company placed their study under the direction of a systems and procedures group. They decided to obtain the help of experts in this new area. They retained a firm of certified public accountants who, since 1948, had been studying the possibility of application of electronics to business systems. Various electronics manufacturers were also invited to participate.

The first problem they encountered was a set of misconceptions which prevented some divisional managers from giving electronics serious consideration. Most of these dealt with the high cost of the equipment and its supposed lack of ability to fit into business operations. However, study showed that a break-even point could be reached when a computer was used as little as 2 hours a day on four clerical operations.

Savings were computed on the basis of salaries, space rentals, and equipment depreciation applicable to those clerical jobs eliminated in four limited routine applications. No value was given to such in-

tangibles as more prompt reporting, the ability of management to make more informed decisions quicker, and possible reduction of investment in inventories. It was believed that had these important factors been included, a break-even point could have been reached with fewer applications and less computer time.

As a result, approval of the directors was obtained for an electronic installation.

Soon after the decision was made to go ahead with an electronic computer, the Louisville team decided that the operating management of the five appliance departments needed indoctrination in the use of computers. This was especially important if the program of modernization and centralization of Louisville was to proceed smoothly. Since 1941 General Electric had been following a policy of expanding its productive capacity by building small, geographically decentralized plants. In addition, the company had been actively pursuing a program of decentralization of management responsibilities. The data-handling and -processing function, up to this point, had been under the direct administration of each of the department managers. This meant each could and did develop his own control and reporting system. Only the general accounting system was under the functional supervision of the central home-office accounting staff, for policy purposes. The introduction of the electronic computer would disrupt this system of relationships to some extent.

Early meetings with the operating management stressed the fact that there would be no major realignment of responsibilities. The computer group would serve only as a service center. Analysis of reports and actions resulting therefrom would still be the responsibility of departmental managers. The meetings served to provide the managers with a forum to ask questions and to work out their individual and mutually shared misgivings and problems.

The same degree of understanding was required of the management and staff reporting to the department heads. It is at this level that the actual working out of the details takes place. Over a period of time the foremen and the various staff members had developed close relations with decentralized data-processing groups. The prospective loss of this personal contact could give rise to misgivings. Under the old system, fast feedback of data was possible. When a figure was questioned, a call or personal visit could quickly clear up the issue. The same degree of personal rapport would not, among other things,

be possible with a centralized electronic system. This could lead to questioning of the accuracy of the data reported.

Decentralized data processing had afforded a maximum of flexibility. Requests of the operating management for particular data or reports could be met with a minimum of explanation as to what was wanted by the managers.

Centralized data processing requires careful scheduling and setting of priorities. Requests for particular data or special reports call for detailed explanations, which were not required when the managers and the data processors worked so closely together.

The group discussed potential computer applications with executives from all functions of the business—financial, marketing, purchasing, the manufacturing groups, and so on.

Points stressed at these meetings included:

1. No change need be made in existing data-collection procedures or in the reports.
2. All original documents would still be returned to the originating department.
3. Clerical-cost savings would result.
4. The managers would be able to receive additional information to assist them in performing their responsibilities more effectively.

Immediate and short-range applications of the computer which were discussed included:

1. Data needs for payroll.
2. Material scheduling and inventory control.
3. Order service and billing.
4. General and cost accounting.

Longer-range projects for the computer were also considered. Feasible future applications included:

1. To prepare monthly, quarterly, and annual budgets. Various suggested combinations of product mix would be used to prepare complete budgets and forecasts, employing the previous week's information on labor and material cost variances.
2. To improve the work-load balance on automatic-laundry assembly lines. Each of these calculations required 50 hours of desk work, whereas the computer could prepare one in a few

seconds. It would be practical to prepare several hundred possible solutions and choose the best one. When production rates changed, new balances could be prepared for immediate use.

3. To handle sales and inventory reports. Later still this could be extended to include initial phases of short-range and long-range projections and forecasts, including multiple correlations with economic and other factors affecting the sale of products.
4. To prepare factory machine-loading schedules.
5. As a later possibility, to coordinate materials, machine loading, and labor loading for production control.
6. Eventually to do long-range forecast of sales, a forecast employing such data as birth rates, family formations, disposable income, the level of employment, availability of electricity in homes, and comparisons of competitors' models and prices.
7. Eventually also to establish an integrated system which would provide dynamic distribution analysis. It would provide for management an up-to-the-minute picture of the retail trade and of distribution pipelines. The purpose of this integrated system would be to enable management to adjust selling effort and factory effort to make maximum use of resources for more profit.

As a result of these discussions, it was mutually agreed to undertake the short-range projects in the following order:

1. Payroll.
2. Material scheduling—inventory control.
3. Order service and billing.
4. General and cost accounting.

The procedures group determined to select equipment whose cost was fairly certain to be recovered, while at the same time choosing equipment able to handle more extensive and potentially more profitable applications in the future. For this reason search was limited to large-scale general-purpose computers. As they were eager to start the program, they leased the only large-scale machine readily available at that time, the UNIVAC.

Lyons, Ltd., a restaurant chain in London, England, had a similar experience, except that no commercial machine was available at the time they became interested. They hired several electricians and radio technicians, none with computer experience, and in less than two years developed a working electronic system. The system now prepares

weekly payrolls for over 30,000 employees. Special devices were designed to check the accuracy of the input data and to insert new employee names into the proper sequence in the master file. They are planning to use the computer for sales analysis and other purposes.

Because of the interest which was created by their installation, Lyons has expressed willingness to develop similar equipment for other companies.

General Electric organized an installation group to prepare for the computer. The primary source of readily available personnel for this group was the business-procedures section of the company. This section had men:

1. Who were familiar with the operation of the business.
2. Who had training in previous systems and procedures.
3. Who had at least a college diploma and, in many cases, a master's degree in business administration.

Psychological tests were used to choose men from this group. The tests were designed to select personnel with high intelligence and ability to think logically and reason abstractly.

Several members of a certified public accounting firm were retained to provide expert help in the system installation. A course was started to train people in programming the UNIVAC. The training was done at the manufacturer's school in New York City. By fall in 1953, about a half-dozen programmers were sufficiently trained so that they could start on the actual programming and coding of the payroll routines.

The build-up of the programmers continued. By using the facilities of the manufacturer the cost of training was kept down. Retaining the certified public accountants to aid in the programming made it possible to minimize relocation of personnel once the total program was coded and installed on the UNIVAC.

General Electric's approach was to schedule, as a first application, a program which called for great accuracy and which at the same time would relieve the staffs of the various operating departments of considerable routine clerical computation; thus it would provide savings substantial enough to be evident to all levels of management. If the computer handled the payroll accurately, it would alleviate some of the apprehension as to accuracy of the system. At the same

time, reduction of the cost of routine clerical computation was an objective which operating executives could appreciate and share.

However, original recording of time and production data remained with the operating departments. This substantiated the policy that the only change would be in the processing. This was also necessary because the computer-installation group reported directly to the washing-machine department.

A third benefit of the application chosen was in the extent of the service which the computer could provide. It was estimated that approximately one hundred different types of reports would be prepared for all levels of management. These reports would be prepared from the same output tapes as were used for payroll calculation, rapidly and inexpensively.

Originally it had been hoped that the first running of the payroll could be done about May, 1954. Before this was feasible, however, it was necessary for the manufacturer to deliver a high-speed printer. The printer was not available until summer, and other difficulties, primarily mopping-up details, slowed conversion so that the first trial run of payroll, in parallel with the actual payroll, was not achieved until several months later. The first solo run occurred in early fall of 1954.

It is difficult to assess all the facets of this immensely interesting pioneer effort. The group at Louisville has been reconstituted, with leaders receiving promotions elsewhere. Company executives have indicated that there may be somewhat less emphasis in the future on further clerical routines as early applications, and greater emphasis on the types of applications which were considered "secondary" in original planning—the use of the computer on mathematical planning to achieve better production planning and better marketing analysis. It is still believed that the clerical applications are feasible, but that greater pay-offs await in the other areas.

It is expected that, on the average, initial applications will occupy the electronic system less than one shift. The remaining time will be available for further applications and for mathematical work.

General Electric did not place production control and scheduling on the schedule of applications which would be among the first to be placed on the computer. Instead, they set up a special group to study the problems which must be solved before a successful computer ap-

plication of production control and scheduling can be made. This permitted the company to hire the necessary experts, not available within the company, and to integrate them into the organization with a minimum of disturbance. This group of experts also reported to the washing-machine department.

The same group can be used to work on problems connected with other future applications. Among those contemplated is the development of a method for sales forecasting that can be related to the programming and scheduling of production, purchasing, sales effort, and financial needs.

A by-product of the investigation is the discovery that it is feasible to link the data systems for several plants that are geographically separated. The company has considered the preparation of payroll for the Erie, Pennsylvania, plant on the Louisville UNIVAC. The data can be transferred rapidly and economically, either through input media or by teletype.

New tools, such as new methods of mathematical analysis, were found to have many implications for the proper organization of an electronic data-processing system. In addition, the analysis has provided economic benefits even before computer application. Dr. Melvin Salvesson, formerly of the UCLA Management Science Project, has reported an improvement in production control which saved several hundred thousand dollars.

Organization Problems. No pattern has been evolved as to where the computer group should be placed in the company organization. Various arrangements have been tried. In some companies the computer groups report to the controller, in some to the chief accountant, and in others to the heads of purchasing, production, sales, or production control; in a few cases the computer groups report directly to the president. Some large corporations have more than one group. For example, one has a group responsible to the accounting function, and another group in the production department located in a different city. Another large company has assigned to different divisions the responsibility for experimenting with different types of equipment. A large merchandising corporation has followed a similar approach, assigning different input and storage devices to different stores, where they are installed in different types of selling departments.

The existence of several computer groups within an organization,

while offering certain experimental advantages, has already led to some internal organizational conflicts. Difficulties arise because each of the groups tends to compete in several ways—e.g., for skilled personnel in an extremely tight labor market, for the attention of top management, and so on. Each group tries to prove that its approach is the best, and it is difficult for top management to determine the degree to which each should be encouraged. Different approaches are desirable if, for example, one group is interested in clerical-cost reduction and another is primarily concerned with analysis and production control. But in many cases management finds it hard to judge these experiments because of lack of experience in dealing with this new field.

In some companies each group has been permitted to choose the equipment it feels is best, with the result that machines from different manufacturers have been chosen. So far, manufacturers have tried to discourage firms from assembling an electronic system from several sources; some equipment has been designed deliberately to make it incompatible with other manufacturers' machines. If, for example, input media are not compatible (some machines read "five-hole paper tape," some read "seven-hole paper tape"), then the two groups cannot assist each other to balance loads or to substitute during breakdowns, without expensive rehandling of the input media. The coding and programs may be different, so that even if the media are compatible rehandling may be necessary.

If the different systems are ever to be integrated, then additional investment for conversion equipment will be required. Programs may have to be redone. This is a major reason for emphasis on integrated systems, as in the U.S. Steel, SKF, and Chesapeake & Ohio installations.

Programming and Personnel Problems. It is generally believed that it is necessary for an executive to have some understanding of how electronic systems work in order to be able to appreciate the personnel problems which are involved. In large measure the reason for this belief is that new systems will require the services of personnel trained in new techniques of method analysis, and of programming, coding, and operating the new equipment.

One expert has gone so far as to declare that programmers may very well represent a new category emerging in society. A programmer must be a meticulous thinker. Such concepts as "reason-

able" or "obvious" or "comparable" are not satisfactory in his work. He must operate with a set of definite criteria, with all the relationships spelled out.

Herbert Grosch, of General Electric, one of the pioneers in administering a computer group, has declared that a programmer must be a good chess player. Or, failing that, "he must be a person who would play a good game of chess if he played chess!"

The significance of this lies in the fact that a programmer must be a person not only with an analytical and logical mind, but one who has a keen sense of spatial relationships. He needs these in order to visualize the ordering of the various elements in a program and to place the instructions and information in the various storage devices of the computer so that handling of items will proceed to best advantage.

In one comprehensive installation study, for example, it was found that the computer's facilities were always too limited to do all work in one pass every day. Therefore the first step was to draw up a chart which showed the top-level operations for the computer—the way that tapes flow from one job to another. Input and output steps were also charted.

However, in order to do this it was necessary to make assumptions as to the number of tape input units available. If it were found that twelve were required at one time for a major job, this meant that another major job should not be charted to use six if it could be more economically set up to use twelve (once it was assumed that twelve would be available anyhow). Moreover, it was necessary to assume that magnetic drums would or would not be available, and that certain file arrangements and codes would be used, etc.

These determinations are part of the study that should be undertaken before the precise nature of the electronic system is specified. Then, after installation, when specific flow charts are made up, the first assumptions have to be refined. Possible changes may be suggested which might benefit one program but hinder another.

Program policies must be established. These ensure uniformity with regard to such things as tests to determine whether a tape can safely be used for writing (writing erases material already on the tape), or whether the tape holds the list of accounts receivable, which might as well be kept.

From matters such as these it should be evident that handling a

computer calls for abilities which are not precisely like those required for any activity heretofore present in a typical business. Even punched-card operations are considerably different; it cannot be assumed that a capable man from the punched-card department will necessarily prove adept at handling the new tasks. Many such men are studying to make the transition, and it appears as though on the average they will perform capably. However, experience is limited, and so far there are few tests with which to separate quickly the mediocre from the good.

This is important because there is some evidence that in the end extremely capable men may be worth many times as much as those who are just fairly good. In several cases a good program has been found which cut operating time in half over a fairly good one. But there is no way of determining these matters until it has been done. And there is no assurance that some other program may not be much better. Research in the area of generating routines, pseudo codes, etc.—attempts to program the computer so it will aid in its own programming—indicate that companies which can develop a top-notch programming staff may have a tremendous competitive advantage.

Programming Experience. Experience with large-scale general-purpose computers has shown that programming an application usually is time-consuming and expensive. In some instances the original expectations have been exceeded by over 100 per cent.

Testing the first programs for the computer is also expensive. The workers must proceed carefully; it is rare to have a program work out right on the first try. Frequently it has been found advisable to have the computer installed a month or several months before it is running full time on actual work, so that programs can be tested. This means that rental of previously installed equipment must continue during the interim. Most large-scale computers have been run in parallel with older equipment for at least two full routines (such as payroll) before change-over.

Preparation of a single program takes from a few weeks to as long as 6 months, not counting time for testing. In one case, delivery of a computer was postponed for several months, at request of the customer, because the programs were not ready.

So far manufacturers have been generous in their assignment of skilled programmers to assist installation groups. Even so, there is a

shortage of skilled programmers. It has been found that it takes about 3 months or more to teach a person to handle a large-scale computer properly and as much as 6 months to train him to program. Even then there is no assurance that he will be "skilled" in the sense that has been given to that term.

More programmers are being trained all the time. However, whether sufficient will become ready is still a question. At least 10 to 15 programmers and analysts are needed on large-scale installations; some firms talk of hiring many more. The smaller installations, using one or more of the many medium-sized computers, will require at least 3 to 5 programmers. If orders for large-scale computers and for medium-sized computers hold firm, there will be a need for several thousand skilled programmers by the end of 1956. Companies are attempting to anticipate their needs by sending men to the programming schools now being run by computer manufacturers and by some colleges, but the problem may grow acute.

As a result of the scarcity, salaries for good programmers are in the five-figure class. This has considerable significance for the continuing costs of running installations with large groups of programmers and the other skilled operators who are required.

A number of companies have found it worthwhile to start programming their computer a full year before they get their electronic equipment. They have rented a few hours on machines in order to pretest the programs, when necessary. Meanwhile, the programmers are getting a thorough training, both in the abilities of the machine and the requirements of the business.

Equipment Problems. Delivery of computers, and especially of the first models of newly developed devices, sometimes has been delayed. In one case an important output device was delivered 4 months late. In another, a new device proved unreliable. Such delays can add to the cost of a computer installation, even though partly borne by the manufacturer. In some cases they were not contemplated in the original savings studies.

Reliability of well-tested components of electronic computers has not been of much concern to users. In one case a company reported that, over a period of more than a year, more than a hundred engineering changes, some major, were made in the computer, but these changes rarely had caused delay or other concern to the operating group.

Newer devices, particularly for input and output, have been subject to a much greater incidence of breakdown. In one installation a new output device was down over 25 per cent of scheduled operating time.

In the case of some medium-sized machines the "de-bugging" time for the equipment has been relatively short—often a few days have been sufficient. Some larger installations have taken a matter of months.

Future installation studies should benefit from experiences such as those outlined above. Although in some cases this means that savings expectations may not be quite as great as some previously visualized, nevertheless the conclusion of most companies has been that they should have started their studies earlier and more intensively than they did, for the savings from the installations are still substantial.

On the other hand, it can be seen that total costs will be large, after including such other items as space requirements, need for air conditioning, possible personnel displacement, crowded conditions during initial parallel operation, and so on. Failure to install the right system could be a major mistake. Nor can it be assumed that because a computer is "general purpose" it can handle all types of data processing efficiently. For example, in some installations it has been found that the high-speed storage capacity of the machine, or of related devices, is not sufficient to store all the programming steps that the operators would wish for maximum efficiency in running a particular routine. This has meant, in some cases, that a program must be broken into as many as fifty, a hundred, and even more sections. Since each section can run only that part of the data for which it is suited, this means that the data must be sorted before being placed on the input or that all the data must be run several times—either of which is an inefficient use of the computer, as a rule. In some cases the presorting requirement has raised the time required for an application by several hundred per cent over original hopes.

Improved design of the computer or of programs is not the whole answer to this problem. In some cases it will be advantageous for a company to revise its data-handling and accounting requirements to put them more in line with electronic capabilities. This problem has received inadequate attention from accountants.

However, as indicated in Chapter 3, the logical design of electronic systems can be expected to change so that the machines will become

less a revised version of scientific computation centers and more an expression of the much different business computation and processing requirements. Such design improvements eventually may reduce the need for skilled programmers and yet make the machines more flexible and cheaper.

In addition to problems related to the central equipment, there are also some difficulties in connection with the media which can be used for initial recording. Some machines still rely heavily on punched cards, and some place emphasis more on magnetic tapes. Experience has shown that there are some significant advantages to using magnetic tapes: information does not get lost in handling as frequently as with punched cards, since information cannot easily be left out or altered. The inputs may be converted into related sets of answer tapes. These answer tapes show the results of computations, so the situations before and after processing are both available. This record is not now available with machines using only punched cards, as a rule, unless considerable print-out of intermediate stages is attempted.

Another advantage is that errors can be edited more easily, when discovered. In a number of installations an error on about one punched card in a thousand is customary, requiring extensive trouble shooting later. The tape error often can be handled by the computer if impossible codes, addresses, or information are involved. In some cases the computer can be programmed to make a reasonable assumption and go ahead, keeping a record of the assumptions made for later verification.

On the other hand, there are some advantages to punched cards. Tape markings are invisible. To print out a full tape in order to locate trouble is time-consuming, so that the operators often try to avoid this. They theorize as to possible errors and attempt solutions by altering the tape or the program. In one installation the management has insisted that a print-out be made whenever an error on the tape is suspected. With punched cards, on the other hand, the file can be more quickly searched to find the item causing the difficulty.

Present speed advantages of tapes as media may tend to be reduced in the near future. New devices reading a thousand cards a minute are under development, and with punched-card electronic computers they may offer more of the same advantages as tapes. Sorting of card information can be made much more rapid. Tape sorting

is quite time-consuming at present, though special devices to improve this are also being developed.

Tapes are cheaper than cards, per item of information stored. Still, they may cost \$50 to \$100 each, and though reusable, several installations are using many hundreds of tapes, so the investment is not inconsequential. Occasionally defective tapes have somehow passed inspection, so that time is lost until the defect is discovered during operations. Foldovers or dust may cause items of information to become lost. It is necessary to handle tapes with care and to keep installations exceptionally clean.

Air conditioning is another problem with large-scale machines, which at present develop considerable heat from their large numbers of tubes. Space requirements and strength of flooring, while not usually critical, must be considered. Power requirements of electronic computers may require special wiring. In some installations these costs were not considered sufficiently in the original estimates.

Sequence of Applications. Another problem of major proportions for operating managers has been to select the best sequence of applications for the electronic system. This problem has been aggravated by the fact that some computer groups have been unable to estimate savings accurately. Underestimates of time required and overestimates of possible savings have resulted in pressures from management which in turn have sometimes influenced the choice of application.

There is some difference of opinion as to the type of application that should be attempted first. Should it be one which is likely to justify the cost of the installation quickly? Or should it be one which avoids deadlines, minimizes contacts with customers or employees, and avoids undue reliance on a new device? In the latter case the savings may not be nearly as great.

On the other hand, many groups believe that it is in this area of analysis that greatest benefits will be derived, not from clerical savings.

In some cases the first applications have demanded great accuracy, with strict time schedules, etc. In such applications the effects of mistakes or mishaps during initial runs may be quite serious. Such errors in the past sometimes have led companies to remove various types of nonelectronic machine installations, even though application groups believed the installations eventually could have been made

economical. One large company reached the following conclusions concerning their large-scale installation:

1. The first concern is to get the computer on a paying basis.
2. Benefits from the first application should be tangible and clearly defined.
3. Considerable savings may be available through use of the computer in areas not involving large clerical operations. This is particularly true of untried areas where adequate equipment for handling large volumes of complex calculations was lacking.
4. Attempts to handle such areas should be made only after competence has been acquired through experience with more familiar procedures.

In another company, virtually the opposite of each of these conclusions has been reached.

Internal Auditing Problems. As yet most internal auditors and public accountants have not expressed much concern about the difficulty of auditing electronically prepared reports. In fact, at various meetings, speakers have reassured the audiences that basic accounting principles will not be changed and that most auditing techniques will still apply.

There is not much experience from which to draw conclusions as to the accuracy of such statements. It does seem as though some problems may arise. For example, a precept of internal control of long standing has been "separation of duties," so that considerable collusion would be required to falsify records. But the number of humanly handled steps will be drastically reduced by some of the new electronic systems.

A number of years ago, an embezzler, immortalized by St. Clair McKelway in *The New Yorker* as the "Wily Wilby," made a practice of returning to his office on weekends and rerunning an entire set of punched cards through to new ledger pages. He managed to pass audit, in spite of pocketings amounting to several hundred thousand dollars (not counting the small bonus the firm gave him for good work).

Almost by definition the new electronic system experts will have to know how to run their whole system.

It appears obvious that close control of input tapes, programs, and output records will have to be maintained, with as much separation

of duties as possible. If there is any slip-up, a single expert might be able to rerun a tremendous volume of transactions, by old standards, in only a few hours.

A major safeguard against this in most present installations is the fact that the expert would not benefit from such falsification, since he does not have access to disposable assets or to means for misdirecting checks.

Auditors are at present talking of reliance on the same original evidences—the papers from which input tapes are now prepared. Outside confirmation is expected to help. However, there is going to be considerable pressure from installation groups to eliminate as much as possible of these original papers, since if they could be prepared automatically, by print readers, by voice recorders, by counters, by direct inputs from cash registers and time clocks, etc., a substantial saving in clerical work would result.

Moreover, even though no fraud is present, there will be difficulty in following through complicated programs of instructions to see that proper allocations are made—that cost figures represent the intent of the policies set by executives. The machines will process so much information, and so fast, that there will be veritable avalanches of data to be studied, unless the controls can be properly evaluated without such detailed investigations.

In their capacity of passing on the efficiency of the data-processing system and the efficacy of the internal controls, some groups, both of internal and of public auditors, have come to the conclusion that they will have to learn the details of operation of these new electronic systems to a far greater degree than others have thought necessary. (Or, perhaps, than they would like, in view of the time and effort required to understand the systems.) While it is true that basic accounting principles may not be changed by the advent of electronics, yet these workers realize that one must comprehend a data-processing system sufficiently to choose the proper check points, if he is to judge whether or not accounting principles are being applied properly and whether or not the internal controls are adequate.

Entirely changed concepts of cooperation between the internal auditors and the operating managers may be in the making.

Research Nature of Computer Installations. Some managements have, perhaps unconsciously, placed heavy pressures on their computer groups to show some quick, tangible results of their efforts.

The executives appear to fail to understand that computer applications are applied research projects in every sense of the term. Long study periods are necessary in order to define, measure, and evaluate the business-data requirements before they can be adapted successfully to the computer.

During the initial study phase, few concrete results are visible. Members of the group spend their time talking, reading, and—preferably—thinking. Only a brief report may be forthcoming at this stage. At best, a few sets of program instructions will be prepared, a few hundred pages of paper.

Yet if this stage is not handled properly, the later periods will suffer. Already there have been instances where special-purpose systems were inadequately designed, as a result of failure to make sufficient preliminary investigation. In one company, for example, an inventory application was installed which perpetuated three different inventory-numbering systems. Revision of the numbering system is a major task, but once accomplished it will result in benefits that are also of major proportions, both in better operating systems, with unnecessary steps and duplications eliminated, and also in more efficient utilization of the electronic equipment. Moreover, if the company ever tries to integrate its information systems, the costly change-over will have to be made anyhow.

Summary. Transition to use of electronic computers has created a number of administrative problems. The cost of the installation is substantial. Selection of proper equipment and competent personnel is not a simple matter. Experience has shown that preliminary estimates frequently are less accurate than for other types of resource allocation.

Conversion of present routines, without improvement or integration, seldom results in the most efficient installation. Therefore a detailed study of the business requirements must be made. These requirements must then be related to the capabilities of electronic equipment.

Presently available equipment is not always as satisfactory as some experts believe it should be. Personnel able to make analyses, prepare programs, etc., are scarce. Training of company employees is usually desirable but does not necessarily result in the required competence.

Provision of better data for decision making is considered to

offer one of the most promising areas for future electronic applications. However, before this can be accomplished in full measure, a company usually will have to adopt new methods of analysis. The whole approach to management planning and control may have to be revised.

Chapters 6 to 10 will discuss these analysis problems. Their relationship to the selection of the most suitable electronic system for a business then can be presented.

CHAPTER SIX

Management and the Scientific Approach

Experience has shown that electronic systems can reduce clerical costs. However, in many instances the real significance of the use of electronic equipment lies elsewhere. Even if an installation increases costs, it may well be worthwhile.

Electronics can serve as a vehicle for the company to study, reorganize, and improve not only the business-data processing and communication systems but also the system of management planning and control. For this reason a number of companies now believe that they should revise their previous approach to installation studies.

As is evident from the data presented in Chapters 4 and 5, when a company begins to study a computer application, its executives face two general types of problems, which may be characterized as technical and administrative. With regard to technical problems, the following conclusions are fairly well established:

1. *The ideal electronic computer for data processing is not yet available.*

Present computers are not efficient for handling the complete accounting function, production scheduling and control, and all of management reporting. Electronic systems do not even readily debit and credit in the accepted accounting sense (although it must be admitted that some experts argue that this is no longer necessary).

2. *After an application has been placed on a computer, it usually becomes evident that the machine can do more than that particular function.*

For example, a computer organized to handle payroll usually can be programmed to do cost accounting for labor, labor reporting, etc. However, as more and more functions are added, it

also becomes apparent that the computer has some limitations. These may result from voluminous input and output or the need for storage. Or, extensive sorting may be required. In some cases the current system does not lend itself readily to application on the computer. Either the system must be changed in order to take advantage of the computer, or else new components must be added to the electronic processor in order to handle the business needs.

3. *While the programming requirements of the computer can be met by training the present clerical staff, a few weeks or months are not enough to prepare them to make efficient use of the computer.*

Inexperienced workers often program many redundant operations. As new data requirements appear, company programmers may find that they have not had sufficient training to know how to adapt the machine to the new problem. And there is no assurance that even with years of experience all the men will become highly proficient on all types of problems.

This is not solely the fault of the personnel. Some companies have included computer engineers in their analysis groups; their assignment is to invent new devices to help get easier solutions to the changing problems of the company.

4. *Whenever anyone prepares a program for a computer, there is always the danger that some important data are being omitted.*

The omission of an item may not be discovered until later, perhaps too late for efficient revision. The problem has also been evident whenever mechanical systems were installed, but it was easier to correct, simply by adding personnel or equipment.

It is possible for a computer program to be checked out much more effectively when solving a mathematical formula than when dealing with a business procedure. A mathematical formula is a complete system within itself, one that can be checked for consistency and completeness before and after solution.

No formula exists today which can be used to show a complete, integrated business system. Each company has its own procedures. In almost all cases the systems are largely the result of a series of semirelated historical accretions.

More important, over the past ten years there has been a

growing need for data for management planning and control. This need has not been satisfied by the accounting system, the production-control system, or by the cost system. Even if the latter were correctly programmed, problems would continue to exist.

These technical problems have their counterparts in what might be called "administrative" problems:

1. *Executives may be disillusioned in the early stages of application.*

Expected savings may not be realized. If an installation is predicated upon successful handling of one routine, and if the electronic system design was oriented to that one routine, it may be difficult to correct or to improve the situation. For example, it takes so long to make an installation for payroll or for order billing that, by time the system is in operation, many premature decisions may be reached as to the capabilities of the machine.

In one case, after two years' work installing a system, the savings achieved offered no pay-out of the original cost of equipment and installation. For this reason, some company executives are impeding further utilization of the computer within their organization, even though what they have learned makes it highly probable that further applications would be more rewarding.

This administrative problem is complicated by the fact that first applications often are chosen to show quick savings so that management will be satisfied. Large areas which in the long run offer more substantial profit are neglected because the computer application group fears that management will call the gains intangible. These areas of potential benefit often involve the method of organization and the responsibilities of management, and so cannot be approached without the firm support of top executives.

2. *Interfunctional conflicts may arise.*

The integration of business systems of necessity affects all groups in the organization. Centralization of data processing is often required in order to justify a large general-purpose electronic system. When a company is in the process of decentralization, or has just completed a move toward that direction, this

need for centralization of data processing cannot help but create administrative problems.

Conflicts often have existed in various functions anyhow. For example, animosity between accountants and production engineers over cost allocations has become almost proverbial. The integration of accounting and production in such situations leads to organizational conflicts. Where engineering needs for computation are substantial, the engineers may be able to buy their own computer. If the conflict is deep-seated, in some companies this has resulted in the purchase of two different types of computers. In other companies, where this duplication has been prevented, one group usually tries to take over the other.

3. *As the move grows for placing new functions on the computer, a need for specialists arises.*

Company personnel seldom have the background adequate to meet all the new requirements in a short period of time. Electronic engineers are needed to maintain the equipment. Skilled programmers are required to code the computer.

In addition a new group of specialists are required—men who understand the tools of “management science” or, as it is often called, “operations research.” Such specialists today are in short supply. One company advertised and searched for over half a year in an attempt to hire one. The cost of such a man generally is 20 to 50 per cent higher than that of specialists already working in the company.

4. *Unless there is clear evidence of the need, executives tend to distrust and oppose large-scale organizational changes.*

Most persons who have been closely associated with the installation of computers believe that a limited approach is not satisfactory. Morale of the installation group suffers when they see their efforts blunted by enforced limitations. Yet executives are rightly reluctant to undertake substantial reorganization until it is clearly desirable.

Some experts have circumvented opposition by setting their subordinates to work on a particular application while they themselves, and some of their newly acquired specialists, work on the more significant problems. In one company the head of the computer application group has been running the second shift on the approved application so that he and his specialists could have the

first shift available in which to experiment with applications closer to management planning. Of course, top management was not aware of this, and was not expected to learn of it until proposals could be worked out and documented.

5. *Communication is poor between installation groups and management.*

To establish an integrated system is a major accomplishment. Those who have tried this have found that the language they use is not familiar or readily translatable to management. The newness of the field creates a difficulty in itself.

6. *The scheduling of organization changes is a difficult problem.*

Once made aware of the desirability of using an electronic system, management soon realizes that the changes incident upon installation will require careful planning. Alteration of the whole communication system of a company is not a minor matter.

At the same time, executives are confronted by other developments, such as atomic energy and automation. A priority problem exists. To what areas should management give primary attention? Should it be the computer, or the other areas? When should these various changes be put into effect?

The advent of electronic computers, of automation, and of atomic energy has imposed upon today's executive an unprecedented need for developing an orderly process of introducing change, while maintaining a stable organization that can return a profit to the owners.

A survey shows that more and more computer groups are adopting a scientific approach to these management problems. This is a natural development. The most effective use of electronic systems requires:

1. Definition of the business problem.
2. Measurement of the important quantitative factors in the situation.
3. Expression of the relationships between the factors.
4. Formal recombination of the factors.
5. Testing and improvement of the resulting program.

This is a scientific approach.

HISTORICAL DEVELOPMENT OF SCIENTIFIC APPROACH TO MANAGEMENT

On first view one might think that recent developments in scientific management were independent of work on computers. However, the developments are intimately related.

The concept of "scientific management" is not new. Frederick W. Taylor applied scientific methods to certain business operations as early as the 1890s. He found particular success in the field of production, since it was there that management attitudes, largely stemming from an engineering background, were most receptive. In addition, the production process, being largely a physical matter, and more directly under company control than certain other activities, proved more susceptible to the definition and measurement which are basic to any scientific study.

Taylor hoped to extend his work to all phases of management. But despite his efforts, and those of many other workers, this hope was not everywhere realized.

Part of the difficulty lay in the fact that general managers regarded their abilities as primarily an art. On the other hand, scientists then were not interested in business problems. It was not professionally acceptable for scientists to work in commercial fields unless their activities were similar to those which would be carried on in university research departments. The research departments of companies like Bell Telephone, du Pont, or General Electric would be examples.

World War II was the occasion for government-sponsored research leading to the development of computers. The same period saw the enlistment of scientists to aid in the solution of logistics and other decision problems. A notable example was the use of scientists to program British fighter aircraft during the Battle of Britain. Through their efforts the limited resources of the British Air Force were utilized with unprecedented effectiveness.

Another such study led to better scheduling of cargo transport ships. The mathematical models which were developed for this purpose were the direct forerunner of the modern analysis technique known as linear programming.

After the war many of the scientists wished to continue with work similar to that with which they had been engaged during hostilities.

They had found the problems far more challenging, and therefore more interesting, than they had expected. In addition, successful achievements during the war led them to hope that similar results might be obtained in business.

Even those who returned to the university life infused a new set of concepts into their teaching and thus inspired students to enter fields which in earlier years would never have attracted them.

Since the war, the field of scientific effort in management has continued to expand. Two new societies were formed to bring workers together, to encourage exchange of ideas, and to further research. These societies are The Institute of Management Sciences and the Operations Research Society of America. In addition, many other business and professional organizations have devoted an increasing amount of attention to this field.

Even so, it has been difficult for many executives to understand how the scientific approach differs from that which they have traditionally used, and why it is of such importance to the future of management, especially as it is related to the new tools provided by electronics.

Scientific Method. The scientific attitude toward business problems can be exemplified by the technical steps which usually are involved. These begin with an initial exploration of the problem and an approximate formulation of the relationships between relevant factors. This is followed by more precise identification and measurement of factors. Next, the relationships between these factors and the desired results are expressed more formally, often as a mathematical model. Then the model is tested by attempting to provide better procedures, processes, decisions, and so on. In some cases it can be shown that the solution to the problem is an "optimum": no better one can be found under the given conditions. In other cases, the model can be improved.

Not all of management's problems are soluble by scientific methods. Nevertheless, some scientists believe that in time much of management decision making can be formalized by mathematical models. In this sense the use of scientific methods is thought of as leading to a management revolution, contrasted with use of electronic computers and automation, which are said to be creating a second industrial revolution.

The scientific approach is not confined to the use of any particular technique or mathematical method. Nor is use of the approach limited to any group of persons such as a team of scientists who are working

on a particular problem. The scientific method is a general concept which anyone can adopt. It emphasizes a logical approach to problems with definitions, objective measurements, and formulations, which other workers can repeat and test for themselves.

In practice the use of this approach is often so similar to nonscientific methods that it is difficult to make a distinction. In both methods a problem usually is broken into manageable parts, these are assessed, then the parts reassembled into the solution for the whole. Differences lie in the extent to which the problem is rigorously defined, the way the measurements of the parts are carried on, and especially in the way the relationships between the parts are expressed and the way they are formally recombined and repeatedly tested. In business, the process also includes communication of the results back to the decision makers so as to provide for action on a continuing basis.

Installation of electronic computers is not the only force which has brought about the need for the scientific approach to management's problems. There are many other factors which have encouraged executives to seek the aid of scientists. Among these are:

1. Growth of companies, geographically, in terms of product output, number of employees, and so on.
2. Diversification of product line.
3. Technological developments, in nuclear physics, electronics, electrochemistry, etc., including automation.
4. Changes in the social environment, including changed attitudes among employees and executives.
5. Increase in size of investment required to build new plant and equipment, or to undertake new research projects, or to develop customer acceptance for new products.
6. Developments in psychology, "econometrics," sociometrics, etc.

As a result of these developments there is an increasing need for methods whereby managers can rationally select the best course of action—one that minimizes risks while taking full advantage of the opportunities afforded by changing conditions. New methods are required for defining concepts, establishing and analyzing the logical relationships between the key factors, and reporting the results in a way that will enable the executives to select the best program from among the many alternatives available. In addition, a system is required that will test the operation in order to determine whether it is

proceeding according to program, and that will provide data with which to test the program itself.

Groups which study the use of computers for processing data usually become involved with these other problems. By thinking of the electronic systems as communication channels, personnel closely involved with the installation quickly come to realize that attempts to solve basic problems in turn have a decided effect upon decisions as to the requirements of the data systems and, consequently, on the computers themselves.

For example, as one company decentralized its sales operation geographically, it found that it required quicker communication of data to the home office in order to schedule the central production facility. This meant that data had to be transmitted over long distances either by messenger, mail, or teletype. The company has found that each of the media they can use imposes different requirements upon the computer.

If decision making is decentralized and production is not an urgent problem, then the requirements for communicating information to the central or home office may be reduced. The only data transmitted may be periodic financial statements sent through the mail. For example, in one case where completely integrated divisions were established, each division required a great deal of data for its own operation, but the home office wanted only reports which showed financial operations for a period to compare them with the financial budget submitted earlier. The company contemplates installation of smaller computers at each divisional headquarters.

Computers may take over a great deal of current scheduling and production control as further strides are made in automation. These computers may not be entirely similar to the computers described earlier for data processing. Some may have analog features (to be described later). At the same time, use of such equipment should eliminate many of the current requirements for data processing.

A number of recent applications of scientific methods to management problems have taken place outside the computer field, and duplication of effort occasionally has taken place. For example, one company recently laid plans to start an operations research group and a separate computer-applications group. At the same time, it was expanding its analysis and control group for management controls in the controller's office. Conflicts were inevitable and have arisen.

Only a few companies have had sufficient experience to develop a well-considered policy in this field. In one case, the computer group was transferred from an independent status and placed under the controller mainly because as it expanded it entered the operations research area. Meanwhile, the operations research department was expanded. Management authorized the operations research department to establish several separate research groups and to expand their function to include all analysis—long-range and short-range—but to coordinate their efforts with the computer group.

The problems of handling such conflicts are described in Chapters 7 and 8. The remainder of this chapter will be devoted to an examination of the methods of the scientific approach and an appraisal of its future.

Use of Scientific Methods in Business. Why have scientific methods received so much publicity of late? What do they really have to offer?

The businessman whose experience covers a period of time has reason to be skeptical. Scientific management, as propounded by some overenthusiastic followers of Taylor about the turn of the century, by the leaders of the "technocracy" boom during the 1930s, and by other lesser movements, has promised much without achieving all that was expected. Even the punched card was heralded by some as the final solution to management's problems. Today the campaign is for management planning and control, with "decentralized" management. Yet problems persist.

In what way can the scientific approach improve upon present practice in planning and control? What *is* the management-science approach?

In the first place, there is no new "scientific method," different from any which has been employed by some businessmen in the past. The difference lies in the fact that the ability now exists to perform in an organized and systematic fashion some of the management planning and control functions which up to now have been carried on piecemeal. Just as new tools have become available for the physical processing of data, so now there are new tools for business analysis. These new tools are primarily mathematical and statistical in nature.

No single mathematical method or group of mathematical methods exists today which are of primary importance for business use. Tools have been used for the solution of particular management problems such as:

1. Production control.
2. Inventory control.
3. Financial management.
4. Location of distribution outlets.
5. Transportation choices.
6. Transportation scheduling.
7. Investment in new equipment.
8. Replacement of old equipment.
9. Executive compensation.
10. Market forecasts.

Although certain tools have found most usefulness in one or a few particular areas, the capable analyst is always alert to the possibility of using any tool which may prove to be suitable. Among his tools are:

1. Linear programming.
2. Dynamic programming.
3. Calculus of variations.
4. Information theory.
5. Communication theory.
6. Sampling theory.
7. Stochastic models.
8. Monte Carlo methods.
9. Servo theory.
10. Game theory, and others.

These are not necessarily distinct methods. There is no hard and fast line between them. Each represents the work of a group or several groups of investigators who usually have concentrated on a certain type of problem; history has given a name to their work, and thus distinguishes it from other research efforts. As a result, it is difficult to classify these tools in a way that is helpful to the businessman. Even the terminology used is not consistent.

But this is not the primary point. Generally speaking, the application of the scientific approach is still in the first stage of experimentation and partial application. It may continue in this state for a number of years. Much of the work in this field is theoretical. Practical applications will follow later.

This early stage of development offers both an advantage and a problem. The advantage to businessmen lies in the fact that refine-

ment of many of the mathematical tools has not yet progressed to the point where it is difficult for the average executive to obtain a fair understanding of any particular tool if he is willing to make a reasonable degree of effort. The problem arises because there is such a variety of tools. It is difficult to foresee which will become of significance to him now or in the near future, and which will be less significant.

Knowledge of techniques is less important than understanding the purposes that the tools can serve. However, some knowledge of the techniques is required in order to achieve this understanding. The techniques are predominantly mathematical. They are used to establish models. In the present stage of development, the models frequently depend on oversimplified assumptions. As time passes, models will have to be refined. Business will require development of new concepts, improved methods, new techniques, more suitable units of measurements, etc., before a well-developed management science can emerge.

New methods, many of them adapted from other sciences and disciplines, are continually being investigated. Since methods are changing so fast, study of the field must be continuous, and related to business requirements.

The evaluation of the newer tools depends upon the ability of the executive to develop certain conceptual skills. These skills include the ability to see the enterprise as a whole, to know whether objectives are mutually compatible and valid, to recognize how various functions of the organization depend upon one another, to determine which assumptions must be made in order to allocate resources in an optimal manner, to recognize various alternative courses of action and their potential results, and so on.

Mathematics is the best tool with which to achieve the coordination and communication of such concepts. It can represent conditions and events much more concisely and clearly than can be done in any other way.

For this reason mathematics often is called a language. As with a foreign language, mathematics sometimes is difficult to learn and to apply. But the essence of most mathematical concepts, of a type useful to business, is only simple logic. It is not too difficult to learn certain principles of mathematics which will enable the businessman to improve his conceptual skills for managing an operation. Moreover, as

the mathematical tools themselves are improved, it is likely that such knowledge will become even more useful and perhaps competitively imperative.

Already a number of applications have been made which illustrate the use of the tools. A railroad has developed a mathematical model of its freight-car operations which was used by the managers to make decisions so as to increase the average use of a freight car from $1\frac{1}{2}$ to almost 3 hours a day. A life-insurance company has made a statistical study of the causes of turnover among its younger female employees, which enabled the personnel department to cut the turnover by about 70 per cent. A large manufacturer has pictured its capacity requirements for a new plant in a way that saved 20 per cent in making a 20-million-dollar installation. A distributor has rated its profitable items so as to increase sales, while using fewer salesmen, and to raise profits over 50 per cent. A metals manufacturer has doubled the speed of its customer service. All of these and many similar achievements have been reported as resulting from applications of the tools of management science.

In a number of cases the tools were used to describe situations which the businessman already understood fairly well. In such cases translation of the manager's concepts and ideas has served primarily as a means for experimental test of the models. But more often the situations were not so well understood as was thought at first. Use of mathematics for these problems has established the concepts more clearly, and sometimes has uncovered concepts which were embedded in long-standing practices or rule-of-thumb judgments. Thus, using scientific methods, the executive has been able to refine his concepts.

An example is the application of mathematics to production and inventory control so as to add exactness to the concept of "exploding" a bill of materials. By stating requirements mathematically, improved systems have been developed with which to pass information from one department to another. These systems short-cut former procedures, which actually were more complicated than the work of developing the mathematical models and using them. The old systems could be made to work only through much human effort and expediting.

Improvements in Method. Scientific attempts to improve the quality of management decisions through use of more advanced mathematical techniques are now under way in a number of companies. The increased use of statistical sampling is an example. When a mass of

accounting data is involved, satisfactory managerial conclusions usually can be drawn from studies of much less than 100 per cent of the data.

Other examples of modern mathematical developments are easily found. Some mathematicians are attempting to record and analyze data concerning events through the use of matrix algebra. New concepts of quality control, based on statistical measurements, are being applied to the industrial process. Statistical methods, known as design of experiments, are being used for such matters as study of the inter-relationship of the production processes and the quality of the product.

In the past, most methods of work measurement and production analysis have attempted to measure performance at many individual stages and to use each measurement to control the process at that stage only. The new approach is to attempt to find out more about the whole production process, and how changes in particular manufacturing methods can affect it. This is done through the use of small samples scientifically selected and analyzed as a group. More precise answers can be obtained in this way at less cost. If the system is properly designed, the analyst often can call management's attention to the need for taking action while the process is still in operation and before it goes out of control.

In the near future it is expected that more and more monitoring for this purpose will be done by automatic measuring devices linked to electromechanical control systems. But this development will be possible only when the relevant production factors can be identified, measured, and the relationships between them clearly expressed.

Scientifically formulated concepts cannot be developed for the solution of all types of business problems. Where the factors for decision are not clearly identifiable and measurable, where useful relationships between them cannot be established, then human judgment will have to be used, as it customarily is at present. These situations, many of which are primarily concerned with personal relationships, constitute the bulk of business decision making today. Nevertheless, the scientific approach can provide a better analysis of those factors which can be identified and measured, and it can lead to a more objective analysis of the remainder of the situation.

Application of Scientific Method—Case Study. The recent experience of one company illustrates a number of important points which are involved in the application of scientific methods to business problems. One of the first matters of concern in the scientific approach is

establishment of the frame of reference for the situation. This determines the direction in which the investigation should proceed. In the company cited the major problem was improvement of the quality of the product, without substantial increase in cost. The analysts concentrated first on the technological problems, and then turned to managerial aspects.

The first step called for a thorough understanding of the characteristics of the product, the specifications which customers wanted, and the way in which the production process attempted to meet these requirements. The purpose of each production activity had to be determined as it related to achievement of the desired characteristics. The required tolerances at each point on the production line had to be determined, units of measurement for this purpose had to be chosen, and the best methods of production ascertained.

Much of the project time was spent on this topic. The analysts investigated actual shop conditions, studied reports, and discussed with research and production personnel the reasons for the behavior of the various physical processes. From this investigation the group set up a conceptual model of the way to make a high-quality product. The conceptual model was first established in rather general, nonmathematical terms, and its validity tested both by discussion and by using it for suggesting changes in the production process.

Following this, the model was reduced to mathematical expression, which made it possible to vary different factors and to measure their effect on the characteristics of the final product. After careful analysis it was possible to make definite statements as to what improvements should be made in the production process, which factors were critical, and the degree of control which should be exercised over them.

The second step involved consideration of market demand and other managerial requirements, such as minimization of inventory levels. The model was expanded to take these factors into account. Now the analysts could determine *how* the product should be built, in view of the quantities of the various classes of product desired. Using the model, it also was possible to determine how production tolerances at specific points should be altered in accordance with changes in demand for various classes of items.

The significance of this type of study does not lie in the use of any particular mathematical or statistical technique. In research work, often there is a danger that a technique may be applied for its own

sake. Someone learns that a particular technique has produced a helpful result in one situation, and so he attempts to apply it to another, without sufficient study of its fitness. Ability to define the objective is fully as important as the ability to apply particular techniques.

A major obstacle to adoption of the scientific approach seems to be a gap between management, who have the ability to define problems and to rate their relative importance, and the scientific analysts, who know the tools but may try to apply them without fully understanding the significance of the problem or without being able to communicate with the managers in order to find this out.

Several other aspects of the situation merit attention. To complete such a project successfully it is necessary to have top-management support, acceptance by operating management and personnel, and a capable team that has the proper balance between experience and training, and whose members can work together.

The team must be able to take advantage of a scientific approach. Partial answers are not sufficient. Apparent solution of a part of the problem may not improve the over-all picture. For example, if the quality of the raw material (in the example discussed) had been further improved, the cost of raising the quality would still have been more than the increased revenue. Major improvements, which actually increased the profits, were only to be found in the production process.

In addition, the study did not stop with the physical flows and activities but went on to consider the profit-planning aspects of the situation. For this it was necessary to establish clearly and precisely the data needs for management planning and control at all levels of responsibility. At this point the requirements for electronic data processing finally could be specified. A model, showing expected data flows, could be built.

Model Building. Earlier in the chapter it was stated that the scientific method is characterized by careful description of the entities involved, measurement of the relevant factors, and establishment of the relationships between them in a conceptual framework which can be tested and improved by experiment or observation. Perhaps the best way for a businessman to visualize this process is in terms of "model building."

A model is a representation of reality. It tries to retain as many of the important characteristics of the situation as can be handled by the

investigator. But it leaves something out in the interests of simplicity.

A physical model of an aircraft may look so much like a plane that a person who has seen only the model may recognize the actual plane the first time that he sees it. If this recognition is all that is required—as for recognition of enemy planes in combat—then the fact that the model left out many of the internal features of the real plane is immaterial.

Similarly, a mathematical model or a work-flow diagram is a symbolic representation of the structure of the business problem. The model attempts to state all or most of the relevant structural, quantitative relationships. But inevitably it leaves out some of the details, again in the interests of simplicity. Relative simplicity is required for effective communication and analysis.

What is the value of such models to a businessman? In what way does mathematical representation of relationships hold promise for making better decisions?

Most business decisions are made with the assumption that many past relationships will continue. It is expected that what has happened before will continue to happen, barring unexpected influences on the situation. Departmental cost comparisons now drawn up in business, for example, are based upon this type of assumption. The figures for this year and for last year, same month, or for this month and for last month, are listed in adjacent columns on a report. Obviously the comparison is meaningless unless the assumption can be made that the two periods have some continuing relationships, despite obvious changes. Any explicit formulation of these relationships is a model.

Construction of a model of the work flow is the first step in studying a business routine for application on a computer. The various individual operations of a program usually are quite numerous. The relationships between them are complex. It is not possible for the programmer, however skilled, to keep all of the details in mind. The problem must be sketched out in terms of the major flows. These are the input sources, tape units involved, major processing steps, the types and quantity of storage involved, and the output. Each of these then can be approached as a separate problem. The programmer must keep in mind the necessity for integration of each with the other major sections of the work-flow model, but he can concentrate on details in a narrower area. Each step thus drawn up is a submodel. In this way a "picture" of the process is laid out for study and analysis.

There are many types of models and many methods used to develop them. Because of this diversity, it is useful to classify models into three general categories—descriptive, predictive, and decision.

Descriptive Models. A descriptive model states in condensed, mathematical form the measurable relationships which appear to exist in a business situation. It attempts to portray the situation as it exists, either during a period or at a point in time. As observations indicate relevant differences between the model and the actual circumstances, the model is changed so as to provide a more accurate description.

The best known and most useful of descriptive models in business is the accounting system. The accounts are so closely connected with business procedures that it is sometimes forgotten, especially by accountants, that the accounting system is only a symbolic representation and not the actual circumstance. It is important to remember that the purpose of accounting is to mirror, or “model,” the business situation so that managers will be able to understand and to control it. If the two are not in line, it is the accounting system and, specifically, the amounts in the accounts, which should be adjusted.

The cost system is a separate model. Although usually tied in with the regular accounting system, actually it can be held quite separate from it. Cost accounting starts with a group of cost figures, classified according to form (materials, labor, taxes, rents, depreciation, supplies, including all the “overhead items”), and, based upon some analogy with an observed physical relationship of these resources to the products or departments in which they are used, reallocates the costs into product or department groupings.

Other descriptive models are frequently used in business operations. Fundamentally the systems of production control, inventory control, time study, the inspection and testing procedures, sales analysis, and so on, are descriptive models.

A descriptive model which has become of increasing importance to businessmen in recent years is that which has been developed to represent our national economy. Various national-income concepts, and especially such items as “Gross National Product” and “Personal Disposable Income,” etc., have been found useful in assessing the current economic situation and in attempting to forecast how the course of business will affect the sales and other activities of a particular company.

In Chapter 8 and in Appendix 4 a more detailed discussion will be

devoted to a new method for constructing a model of an entire reporting system.

Predictive Models. Any descriptive model can be made into a "predictive" model if it incorporates a forecast of one or more of the factors. If the model is sufficiently accurate, the other factor or factors then can be predicted. In other words, since the model shows the relationship of the other factors to the forecast factors, an estimate of the latter in effect also makes an estimate of the former.

Predictive models still do not indicate the course of action which should be taken. The manager must make this choice, using his judgment. However, since most management problems deal with future events, to the extent that important considerations can be predicted the models are extremely useful.

The most common of predictive models in business are budgets.

A budget is a formal plan for the future operations of a business. The purpose of the plan is to establish some sort of prediction for each particular operation, and to coordinate the various individual operations so that each responsible person will have an idea of what is expected of him. The total budget is then an expression of the total expected expenses and revenue, with the resulting profit or loss—or, in the case of a cash budget, the expected receipts and disbursements.

Budgets can be prepared because past experience gives those in charge a pattern of relationships with which to work. If certain items are estimated or arbitrarily set, then others can be constrained or will tend naturally to fall within certain limits. For example, if sales are to reach a certain amount, then a certain amount of goods must be available, which means inventory must be produced or purchased. A certain number of salesmen must be hired and paid, a certain amount of advertising must be ordered, and so on. The relationships are not exact, but unless policies and practices are drastically changed, they will not vary substantially within short periods, for most businesses.

In mathematical terminology, budgets are built up from the "independent variables" in the situation. The other factors are "dependent variables." The former are the basic estimating factors, the forecasts of the strategic elements in the business situation. The latter are expected to follow if the forecast is correct.

Predictive models of the logistics problem of the Department of Defense—its supply schedules, etc.—have been formulated by a number

of groups in the various armed services. Partial models have been prepared by researchers at universities and for several private companies. For example, publications of the RAND Corporation, the Cowles Commission, the Management Science Project at UCLA, and the Graduate School of Industrial Administration at Carnegie Tech are frequently concerned with this type of model building. The Air Force and the Navy are engaged in testing and applying the findings of these groups.

Much of the experience gained in the military will be directly applicable to industrial problems. Among companies which have shown an active interest in production schedule models are U.S. Steel, SKF, Lockheed, and Kaiser.

An example of a predictive model is the study which was made for the Seebury Farms, which grow vegetables for the Eastern market. An analysis of climatic conditions, market demand, growing rates of vegetables, availability of help, and other factors resulted in a specific planting program. This was worked out so that a rotation of crop maturities was integrated with the other factors. As a result, overtime was reduced, unsold inventory minimized, product quality increased, and the general profit picture improved.

The basic concepts are applicable to the problems of other farmers, but unless all their conditions are similar, a new study of the factors relevant for their purposes would have to be undertaken. Of course, experience gained in the Seebury situation would be of help.

Decision Models. A group of predictive models, together with some means of choosing from among them the one which fulfills some objective most completely, is called a "decision model."

The primary function of decision models is to tell the user what to do in view of some stated purpose. For example, the manager may desire that future profits be maximized. His decisions are subject to certain measurable limitations, such as the storage facilities available, transportation costs, transportation times, and so on. Given these conditions, there is a set of decisions which will yield the best profit.

Models which determine these decisions have been used to tell the businessman where to ship; what, where, and how to produce; and where to sell. These models often use the new technique known as "linear programming."

Decision models can also be constructed to determine such matters

as the best pricing policy or the best financial structure. They show the effect of various long-range programs on the resources of the company, on the finances, on the production facilities, and on the manpower. Given some "optimizer"—a method of determining the most desired procedure—the models can be used to choose the resource allocation which will produce the most profit.

The range of problems susceptible to decision model building has not been fully explored as yet. Much work has been done, but most of this work is on individual types of problems, primarily those which occur at the operating level. Even here problems such as those which involve scheduling on individual machines have not lent themselves too well to model building. It is difficult to establish a model where work flow must be scheduled before or after a specific machine tool.

Many researchers are of the opinion that, even if such models could be built, they might be of limited value because of the way they would limit the foremen's initiative. The models would have to be extremely complex, so that they could take the various pertinent factors into account. Examples of these factors are machine breakdown, tool breakdown, changes in material, sickness of the labor force, strikes, etc.

The brightest future of decision models lies in the area of management planning and control. Management planning and control is primarily concerned with exploring future conditions. But executives are hindered from examining alternative plans for the future, because of the limitations of present data-processing systems. Applications of the new concepts of information theory and game theory have been handicapped by the primitive state of our knowledge of business decisions—how and why they are made, etc. Usually it is all that a company can do to prepare one financial budget within a given period. To prepare a decision model, based on a number of budgets, will require the use of electronic systems of communication, electronic computers, and new mathematical methods of analysis.

The Future of the Scientific Approach in Business. A model has no intrinsic value. It should be constructed only if it is useful. On the other hand, the fact that the model may not be as elegant as one might wish does not destroy the value of the model if it is properly used. A number of critics have assailed the use of models in business, since it has been found difficult to measure and particularly difficult to forecast items as precisely as these critics desire.

The critics point to the greater precision which has been attained in the physical sciences and declare that, until such precision is reached in the social sciences, researchers have no right to call their techniques scientific.

Admittedly the degree to which identifiable factors can be measured—compared to the influence of unidentifiable factors—does help determine whether or not an approach can be scientific. It acts as a limit on the area where scientific methods can be applied. Precision in model building is related to the difficulty of the problem and the state of human knowledge concerning specific techniques and their application.

Business problems have proved to be much more complicated than most scientists ever realized. For example, during the war a group of scientists developed a rather remarkably effective “search theory” for the location of submarines. After the war some of them assumed that the theory would be applicable to supposedly simpler problems of customer location for retail operations. It wasn’t.

But the fact that usefulness of the methods is limited at present does not mean that they can be safely ignored. The value of the scientific approach, with the development of models, can be judged on two grounds:

1. Is the scientific approach more effective than present practice?
2. Do the models provide a conceptual framework from which continued improvements can be expected, as the dynamic cycle of “concept–observation–improved concept–further observation” proceeds?

In answer to the first question, it is already apparent that useful results have been achieved. The publications and conventions of professional societies have featured many reports of successful applications of scientific methods to business.

A survey of over three hundred businessmen, reported by Caminer and Andlinger in the *Harvard Business Review*, showed that the application of scientific methods to business management is a matter of major interest to executives. The executives’ greatest complaint was the lack of case histories in their particular fields of interest. As the authors pointed out, a reason for this lack is the fact that many companies with experience are reluctant to release this sort of information.

The position is understandable, since the studies usually are concerned with critical policy decisions. Information concerning these would be of assistance to competitors.

As for the second question, the trend toward automation of both office and factory will make business processes more quantifiable and therefore more subject to analysis and accurate prediction. At the same time, some means must be found for integrating the massive flow of information with which the modern executive is confronted. Scientific methods of analysis seem to offer the best solution of this problem.

In the same survey, executives also expressed opinions on this point. They saw a growing trend toward use of this type of research in all areas of American industry.

The essence of the scientific approach in business is the development of policies and procedures that can be continually improved through observation and experiment.

CHAPTER SEVEN

Management Planning and Control

Electronics and mathematics already have been used to improve a number of business routines and to solve certain specific problems. But though such use has saved money, partial applications are not the most profitable use of these new tools, nor are they the goal of the businessmen who are developing their use.

Several different terms have been employed to signify the anticipated "best use" of electronics and mathematics. Among these terms are "integration," "the systems concept," "profit maximization through common-language systems," "clerical as well as factory automation," and so on. The terms are used to describe efforts that are being made to apply the new tools to the management of the whole business, not merely to particular parts of it.

The developments are taking place in management planning and control. They have provided managers with a series of new concepts. The concepts enable managers to formulate company goals and requirements in a more definite pattern than has formerly been possible. To do this it is necessary to integrate company objectives, organization, the method of information analysis, the system of communication, and the whole decision process.

Significance of Planning and Control. In recent years the term "planning and control" has received considerable attention from management. There are two aspects to this term: its general meaning, and the set of concepts which have come to be associated with a particular use.

The more general meaning of "planning" covers the process whereby top management sets an objective, organizes the activities, establishes the authority-responsibility relationships of the managers, staffs the organization, and commences the direction of operations.

"Control" compels events to conform with plans. It is the process of setting specific standards in relation to specific allotments of resources, followed by measurement of progress, comparison with the standards, and making adjustments as needed in order to achieve the original objective. Reported results are then used in future planning.

In its more particular meaning the term "planning and control" has come to be associated with a revival of interest in the profit motive. A number of writers, such as Keith Powlison, in the *Harvard Business Review*, and Perrin Stryker, in *Fortune*, have called attention to the fact that a company's top executives are likely to put several other objectives ahead of making profits. Among these are the desire to be the biggest, or most secure, or best (in a number of ways, down to items such as having shops that cut metal with the least amount of scrap, regardless of efficiency). Some executives would put "statesmanship" first—the desire to improve social conditions directly, rather than relying on competition, or on supply and demand.

No one will argue that businessmen should turn away from the need for giving consideration to such factors as the social effect of their decisions, or that they should look only to the profit figure. The question is rather one of weighting a number of objectives. How much can businessmen afford to pay for the attainment of these other objectives? How should managers relate them to the profit picture?

This aspect of business decision making has become more important in recent years, for a number of reasons. Rapid corporate growth has made management realize that their companies were becoming too big to administer without better systems of planning and control. All companies, regardless of size, have encountered drains of profit dollars as the result of higher taxes, labor demands, and the need for expansion and replacement of facilities. Technological developments and product diversity have also shown the need for greater emphasis on profitable decision making.

While reemphasis on profits by itself often leads to an increased interest in planning and control, the pressure will become even greater if businessmen try to take into account the full range of their objectives when making decisions. Planning and control means more than techniques and tools. It is a concept of good business management.

Dr. T. F. Bradshaw, an authority on the subject, has outlined the profit approach:

By profit planning and control I mean the acceptance of certain objectives. These are the objectives: first, setting a profit goal; second, setting department goals which, taken together, will achieve the profit goal; third, measuring progress against these standards; fourth, making continual adjustments to keep the whole organization moving in balance toward the goal.

To accomplish the objectives of this predetermined goal in the fullest sense, it is necessary to coordinate not only the full range of objectives with the tools of planning and control, but also to integrate them with the organizational structure, the employee incentives offered, the program of management development, etc. Apparently few companies have understood this problem, and so far it has been too early to apply scientific methods for a solution.

DIFFICULTIES IN ATTAINMENT OF PLANNING AND CONTROL OBJECTIVES

While it is easy to state the concept of profit maximization, to put this type of planning and control into practice is a project of major proportions. The new system would affect all aspects of the operations, all parts of the organization.

Psychological and Technical Difficulties. There are always psychological resistances to be met among the people affected; the communication fails at all levels. There are technical difficulties of measurement, recording, and analysis.

People resist change in this direction for several reasons. They resent the fact that they are to be judged and guided more closely. The tools of planning and control are regarded as setting up a system of personal score cards, which too often are used as mere pressure devices.

Planning and control projects have run into a number of technical difficulties. In most cases the accounting data are used as a start. For managerial purposes, these data may not be too relevant. More often than not, the accounting process does not produce the data in time, or in a manner suitable for use in making operating decisions.

Operating personnel usually are accustomed to thinking of production in units rather than in dollar figures. As a result, communication fails. A frequent result is that operating managers keep a set of little "black books" for their own use in making decisions. These "black

books" also reflect what they believe will enable them to defend themselves, as well as to please their superiors.

Conflicting Requirements. Another difficulty in establishing a system of planning and control arises from the fact that different levels of authority have different uses for the same data. They place different emphasis on them. First-line supervisors frequently use accounting information as a mere fill-in on those aspects of the work that they cannot appraise from their actual contact with it. The more removed they are from the scenes of operations, however, the more importance they place on accounting data as a means to judge subordinates and to check on what is happening at the operating level. A planning and control system which is well organized to provide data for the one purpose usually is not able to provide adequate data for the other.

If the upper-level executives are to use the reports for planning and control, the operating executives must be satisfied that the data are accurately recorded, that the expected standard level is reasonably attainable, and that the variables which the system measures are controllable by them, at least in part. Otherwise, a great deal of time and energy will be used up in debate about the accuracy of the accounting charges or about the circumstances that explain the variances.

To obtain this confidence, a close and direct relationship between the operator and the accountant is necessary. This must be reflected in the organization structure.

For many problems it is difficult to forecast the types of data which will be useful. There are two ways that this difficulty may be met, two ways to increase the usefulness of the data. The first is to elaborate the regular reports, so that they include more details. The other is to have a special staff whose duty is to investigate and gather the facts that are needed for a specific problem. The latter method often has been found to be the more promising.

Both methods run into the problem of timeliness. Detailed regular reports require the processing of vast amounts of data, and some staff studies still are required to spotlight needs and to sift the information available for the pertinent facts.

On the other hand, special studies take time, and the range of problems covered at any particular time is necessarily limited.

Inadequate Means for Evaluating Performance. It is difficult for management to assess the benefits of a particular system of planning

and control. Most of the yardsticks available are part of the system itself. The only over-all measurements managers have are the trend of the profits through time, and comparison of their profits with those of other companies. But it is difficult to tell how much of an improvement is due to the system of planning and control, since so many other circumstances also change. Comparison with other companies is sometimes helpful, but again circumstances are usually so different that conclusions can only be tentative.

The "profit" yardstick implied in "planning and control" is not a short-run affair. Obviously no company can hope to prosper if the country as a whole, or in many cases the company's particular locality, is falling into severe depression. Increases in the standard of living for the population is an almost necessary concomitant of the growth that most companies strive for. In this sense it can be said that contributions to social welfare do have a long-range "profit" value to a particular company.

Obviously, however, such contributions are very difficult to measure, and in present practice little attempt can be made to evaluate them. That companies recognize this responsibility, however, can be seen in such things as charitable grants and support of education. Occasionally directors have been taken to court by stockholders' suits seeking to prevent such activities on the shortsighted ground that the gifts cannot be shown to be of benefit to the company. However, it is established that fairly sizable amounts for such purposes can be justified, for their public-relations value as well as for the larger objective of social welfare.

On an inside-the-company level the same difficulty of measurement has appeared. It is theoretically certain that such matters as employee morale, the organization structure, personnel relationships, the planning and control operations themselves, and so on, all contribute to long-range profits. But how this can be translated into standards for the evaluation of individual managers' performance is a problem which as yet has not been solved.

The higher the manager's position, the more important his ability to control these intangible factors becomes. Yet top-management standards are still a largely unexplored area. Some work has been done by groups such as the American Management Association and by business management-consulting firms. But the field has received virtu-

ally no attention compared with the concentrated effort made by groups such as those in production management with their time and motion studies for factory operations.

Most of the standards developed so far relate to physical quantities, cost standards, or financial ratios. Physical standards of output, man-hour utilizations, and so on, are well developed, but companies still can benefit from further investigation of this area. Many can benefit by learning to ignore the dollar figures supplied by accountants, when prices are not under the control of the operator. This alone would simplify and speed many reports. It would recognize the fact that as yet most companies are not able to "profit plan" on the operating-foreman level.

Cost standards have received considerable attention in recent years, and there is a decided trend toward relating "cost centers" to authority-responsibility units. However, the relationship of these units to the over-all company operations, in terms of their profit contribution, is a problem that has been avoided—or, as in the case of one large printing establishment, "solved" by adding arbitrary percentages of "profit" to the work-in-process costs as they move from department to department.

Financial standards involve the use of ratios, of turnovers, of asset-liability relationships, of capital commitments, and so on. These are virtually the only quantitative controls used by top managers in many companies. But changes in turnover, or in asset-liability relationships, are seldom specifically related to profits.

Capital commitments frequently are justified in terms of cost savings rather than profit expectations (except for very large commitments in new plants or new products). In fact, it is only in an instance such as the study of the effects of introduction of a new product that the company-wide profit effect is likely to be presented, together with careful quantitative analysis to support the recommendations. In later evaluations, however, the "profit" contribution of the new product again is made on a cost-accounting basis. Cost accounting measures the direct revenues and expenses, plus an allocation of other expenses, without demonstrating the marginal or other effects such as those resulting from the decrease in attention paid to other products.

The top-level profit standard which has received most attention in recent years is the "return on investment" standard used by du Pont and General Motors. The success of these companies has led to con-

siderable publicity for this type of analysis, and it probably represents the highest level of profit-planning analysis which can be achieved using present systems. The approach is to assume that the over-all company profit will be satisfactory if each decentralized operating division can earn a satisfactory return on the capital entrusted to it. Then, in the absence of negative evidence such as strikes, price-level changes, etc., the manager is assumed to have been successful.

Organizational Problems. The difficulties inherent in a profit-oriented system of planning and control are highlighted by the problem which many companies are facing at present: What is the best organization to achieve their profit objective? These companies have found that they cannot progress, or in some cases even survive, in today's competitive economy if one or a few men try to do all the planning and control.

Companies such as H. J. Heinz, Ford Motor, and Chrysler grew and prospered under the personal management of a strong individual. However, these and other similar companies encountered difficulties. The first of these came with the death or retirement of the dominant individual. In few cases had adequate successors been trained to continue the centralized direction of the enterprises. Even where this had been done, however, it frequently was found that conditions in the industry had changed. No longer could one man adequately plan and control the diverse operations. Technological specialization, as well as advances in the techniques of management, had come into the picture to the extent that no one person could be expert in each field and relate all of them in the decision-making process.

In the typical large company, staff experts in the various fields of management, such as personnel, systems work, advertising, quality control, industrial engineering, economic forecasting, and so on, have found that to operate effectively they have to "have the ear of the top man." Since the experts in purchasing, production, sales, research and development, and so on, are also reaching for the attention of the top, the executive has to pick and choose. He must select from the problems that are brought to his attention. But he cannot listen to them all. Moreover, some problems are deliberately hidden from him. As for the problems he does work on, sometimes he cannot get all the information needed in order to make his decision; sometimes he is overwhelmed by the mass of materials offered for his consideration.

The pressure of day-to-day problems on the top executive is so great that too frequently he has insufficient time to devote to long-range planning. Such planning, therefore, takes a back seat. It is often delegated by default to subordinates in a staff position. These men may not understand the operating man's problems, nor do they always fully comprehend the significance of other factors, such as the company's research programs, public relations, and so on.

Heinz, Ford, Chrysler, and many others have sought a solution to this problem in decentralization. Such companies usually start the process of giving more authority to managers by divisionalizing their activities. They bring in new personnel, particularly for planning and control. This type of program usually has shown results.

But the basic problem, optimum planning for profit maximization, has not been solved, and new problems have been created. In other words, the problems have been placed down a level so that now each divisional manager must try to solve his problems and also do his share of the planning while trying to take into account all the factors that top management supposedly should consider.

As a result of the lack of complete planning at the top, plus failure to communicate effectively those plans which are made, the divisional manager seldom feels certain that he knows exactly what is expected of him. Even when he is given a "rate-of-return" goal, as in the well-known du Pont-General Motors system, he knows that in actuality this measurement will be weighted—as it should be—by other considerations, such as community relations, development projects, personnel training, competition in his particular field, and so on. He never can be sure just how much these other considerations will count.

Decentralization has spotlighted these problems. It has awakened many managers to the need for a reexamination of their planning and control concepts. Peter F. Drucker, in a speech before the National Society for Business Budgeting, has stated:

Then take the trend toward decentralization of industry. This is a very misleading term because it obscures the fact that you cannot decentralize without a very much better controls of performance, very much better controls of objectives, than most businesses have ever heard of. Decentralization means that you set up a unit autonomously in such a manner that it operates against standards, objectives and goals rather than against supervision. The major problem is a control problem which very few businesses either understand or have the controls for. Many who go

ahead and decentralize are going to rue the day. Yet, I believe it is a desirable trend.

Summary. Proper organization for planning and control should emphasize neither centralization nor decentralization. The long-range plans and objectives of a company, with their related controls, must be integrated. The operating decisions concerning short-run profit objectives, with their related controls, should be decentralized, but related to the central plans.

Regardless of the problems and difficulties inherent in planning and control, it has a great potential for American business. Planning and control does aim to let the management know where their companies are heading, profitwise. It does attempt to provide an integrated view of the business.

Modern techniques of communication—using electronics, and of data analysis for decision purposes—using a more scientific approach, are directed toward an improvement of planning and control. A discussion of this development is presented in the next chapter.

CHAPTER EIGHT

Programming, Scheduling, and Feedback

In order to indicate clearly the essence of the suggested future development of planning and control, several new terms will be introduced. The same general area is involved, but the approach to business problems will be sufficiently different so that confusion may be avoided by the use of new terminology. The terms proposed are "programming," "scheduling," and "feedback."

The selection of the best plan or budget for a given company, one which recognizes alternative combinations of the basic planning factors, will be called "programming." * Determination of the timing, the specific methods to be employed, and the specific resources to be used in carrying out the program in a coordinated and consistent manner will be called "scheduling." Communication of current information to the proper organizational level for analysis, action taking, and decision making with regard to both programming and scheduling will be called "feedback."

PROGRAMMING

Programming is a more scientific approach to planning. It is a formal, objective attempt to define, measure, and analyze all the relevant factors in the business situation, and to develop thereby the specific policies and plans which will best lead the company to attainment of its objectives. Programming includes simultaneous consideration of factors from the various administrative functions, such as planning, organizing, staffing and direction, and, to some extent, controlling, as well as from the operating functions of selling, purchasing, produc-

* "Programming," as used here, is not to be confused with the use of the same word in connection with operation of an electronic computer—the "program" of instructions given a computer.

ing, etc. It is best exemplified by the mental processes of men like Ford, the du Ponts, Eastman, McCormick, and Swift, while they were directing the growth of their companies. They were "into everything." They learned that they had to have an acquaintance with all the factors in the business situation, since different groupings of them became relevant for the solution of different problems.

Present need for the programming concept arises from the fact that companies have found that they can no longer successfully centralize all important decisions in one or a few top executives. Decentralization of some decisions solves this problem only to introduce the need for centralized decision making of a different sort.

Programming attempts to solve both problems. It tries to take into account all relevant factors, and to spell out objectives in such a way that decentralized managers will be able both to contribute to and participate in company planning. Also, they will receive directions from the top management, which they in turn can use to establish their own plans.

The programming concept is important for effective decentralization of short-range decision making. It is entirely possible for a company to have each of its decentralized managers operate his department with a satisfactory return on investment, yet have the company as a whole not make full use of its resources.

As an actual instance, a processor found that after granting considerable authority to managers of decentralized districts, price wars on their own products would develop in fringe areas between the districts. The company as a whole suffered, though individual managers sometimes made gains.

In another case a large chemical company found that in decentralizing it had created the opportunity for a considerable duplication of effort. Each district was repeating, often with somewhat different objectives, many of the central staff operations of the company and even some of the production and sales efforts. The company has announced that the heads of the various divisions have been relocated in the central home office as the first step in combating this problem.

Both of these companies are in the forefront of experimentation with electronic systems and mathematics.

Programming Requirements. Programming uses decision models to allocate limited resources among a number of competing demands so that the plan will result in the optimum use of resources.

When there are only a few alternatives, then the right answer often can be selected quickly. However, when the number of variables becomes larger, as when a number of divisional managers compete for the resources, then selection of the right answer is very difficult. The problem of optimum selection becomes still more complex and time-consuming when forecasts of future events also must be taken into account.

Company Objective. Selection of the best program requires that the objectives of a company be set forth in a manner which is quantitatively measurable. Profits are always stated quantitatively, in dollars or as a rate of return, but other objectives also will have to be stated in quantitative terms so that they can be interrelated.

For example, the personnel policy of not discharging faithful but inefficient employees—managers as well as others—can be introduced as a specific limitation in the model. This permits the evaluation of the effect of such a policy in terms of profits.

More than the employee's salary is involved; the opportunity to hire better employees is lost. One firm that made such a study decided to spend \$25,000 to retire certain employees so as to improve the administrative process of approving sales commitments. Their study indicated that, by effecting the personnel changes, the company would save approximately \$100,000 a year from reduced investments in inventory as well as from smoother production volume.

Communication Network. The programming concept requires the establishment of a communication network which will transmit information rapidly and efficiently to the various levels of management where decisions are made.

A number of companies interested in planning and control recently have initiated studies of their communication process. They have found that in their organizational structures often there are conflicts which make communication inefficient. Since this is true even when the process is judged in terms of needs that are less exacting than those which will be found in programming, the communication problem will no doubt be difficult to solve.

For example, in a particular company the budget objective given by top management to its staff usually is sent on to operating levels for determination of their specific portion of the plan. But changes in objectives occur as time passes. As a result, those departments which depend on others for their data and thus make up their budget later,

tend to incorporate some of the newer objectives. This makes the budget inconsistent. Time pressures prevent ironing out all of these difficulties, so that eventually rough-cut methods are used to complete the budget in time for directors' meetings.

Even if a better communication link could be established, two other obstacles must be overcome to achieve effective combination of the various planning factors in determination of the best program. These are the amount of arithmetical computation that must be performed and the difficulty of selecting the best alternative.

Computation. The arithmetical computation often can be handled by an electronic computer. But before this can be done the relationships between the planning factors must be analyzed and reduced to an explicit, systematic form. This is not a simple process. Programmers have learned that one of the major dangers in their work is to assume that some relationships persist while others change. To take a time-worn example, the overhead rate used in cost computation is often related to direct labor cost. If technological change shifts the usage of labor, the old rate must be reexamined, which may involve a great deal of computation. More difficult examples involve the relationship between whole departments, or between product lines. In such cases a whole series of relationships exist, requiring a complete reexamination when conditions change.

Selection of Alternatives. Frequently it is difficult to select the best alternative course of action. There are always many possible programs for accomplishing a given objective. The variations include not only different combinations of activities in the same fiscal period, but also possible postponements of various potential activities, such as the introduction of a new product. As a result, though the objective of planning and control may be to obtain the optimum profit consistent with sound, continuous growth and competitive conditions, in practice it has been impossible to determine when a company has reached the optimum profit.

Optimum Allocation. Optimum allocation of effort and resources, as defined by business economists, calls for the use of marginal productivity analysis—increments of resource applied should produce increments of return. In other words, the last dollar spent in a given way should return at least as much in the given application as it might have done in any other possible application. But businessmen have found that the economist's analytical tools often are too limited for

planning purposes. Businesses are not always able to make marginal adjustments. Plants or labor forces seldom can be increased or reduced at incremental rates. It may not be possible to drop below-marginal product lines (marginal as measured on an individual product basis) without over-all sales losses or without violating some operating policy.

Mathematical programming offers hope for improving on the arbitrary standards of the "rate-of-return" method and for overcoming the difficulties inherent in experimentation with marginal adjustments. A program would forecast the optimum level of profits and make the necessary specific allocations of resources. Using such a program, the businessman could move directly toward his objective, making allocations in the most efficient manner rather than attempting to progress by a process of trial and error.

The very nature of mathematical programming as a concept may enable managers to reorient their thinking in more objective, measurable terms. This already has proved to have considerable value in itself. It has been particularly useful to business groups that are in charge of plans for installation of electronic systems, and also for the designers who work for computer manufacturers.

However, caution must be exercised. Much work remains to be done on all phases of program development. Many factors in business problems as yet cannot be measured in quantitative terms. Many relationships appear to be nonlinear, and techniques for handling them still require further development. The human brain still must and presumably always will continue to be used to evaluate factors where information concerning them is incomplete.

Development of the Programming Concept—Strategy and Tactics. Although experience is limited, and no full-scale programming projects have yet been attempted, it seems probable that the programming of an actual company will be undertaken in two major steps.

The first step involves determination of long-run policies—the strategic decisions as to the over-all objectives of the company. These include:

1. Determination of the profit goal (presumably profit maximization).
2. Formulating and measuring the interrelationships between this

goal and other objectives, such as business statesmanship, product leadership, and so on.

3. Integration of these objectives with operating decisions.

The tactical decisions concern problems such as:

1. Where the company will get its resources.
2. Which new resources it should introduce into a going situation.
3. Which resources it should shift to new products, and when.
4. How best to use the resources available.
5. What markets the company should enter.
6. What share of the market the company should get.
7. When the company should expand productive facilities.
8. What personnel, public-relations, and social policies it should adopt.
9. Whether the company should liquidate certain operations or expand in a new direction, and so on.

Due to difficulties encountered in measuring the relevant factors, and in handling the relationships, so far the scientific techniques seldom can compete with strategy decisions made by business managers with experience and resourcefulness. But in spite of such limitations, management scientists believe that it is at the policy level that the ultimate pay-off of new analytical methods will be greatest. Research in this direction is being urged upon top management. The concept is hard to sell. Results will not be immediate or certain.

The second step, the tactical decisions, involves the establishment of shorter-run goals and operational plans which make optimum current use of the resources available.

For example, the tactical program establishes the product mix for the period, the size of the labor force, the current personnel policies, the inventory policies, and the amount and type of productive resources to be used to make the various products.

This policy concept also can be described in terms of "inputs" and "outputs." The desired "outputs" for each function of the company can be stated, e.g., dollar sales by products, the number of units to be produced, etc. The inputs are the various kinds of resources to be applied: advertising, sales force, personnel training, materials, machines, finances, etc. The inputs and outputs are so related that they fit the

policies of the program and thus achieve the objectives of the company in an optimum way.

Role of the Computer and Management Sciences. Communication networks of the type needed to furnish the timely information needed for programming which products to make, when to make them, where to sell them, how to make them, etc., have not been developed as yet. Electronic data-processing systems, along with the mathematical techniques, hold much hope for the future in this area. For example, it should be possible to handle budgetary computations more rapidly and much more effectively.

An example of a tactical program is a decision model developed by the RAND Corporation for a refinery. The model gave the best product mix, considering the productive capacity, the forecast of market demand, and the technical operating limitations. As various forecast factors changed, the model could be run through a computer and a new optimal program selected rapidly.

The time required to program part of an operation usually is not as important as the time required to effect a change in the over-all situation. For example, if winter comes early in the Northeastern states and the storage capacity there of a petroleum company is taken up by lighter products, delay might occur before fuel oil could be moved into the area, regardless of how fast the distant refinery could change its product mix. It is hoped that such considerations can be built into the model in the future to help make better decisions.

Incidentally, mathematicians recently have suggested that such a problem might best be solved through "simulation." Simulation means approximation of conditions rather than precise quantification. Simulation has been used by engineers for many years, but as yet there has been little use of simulation for programming business problems. Electronic computers can be used for simulation. The method offers considerable opportunity for worthwhile research.

Now that digital electronic computers are available, for the first time it is economically feasible to handle the large mass of variables required for budgetary programming. The computers can make logical decisions as well as do mathematical manipulations. Their logical decisions are somewhat comparable to many of those made by middle management—decisions which can be formalized. For example, a computer can be instructed that if a business budgetary program does not result in the realization of a given profit rate, the computer should

reject it and automatically consider a new program. The logical decision rules can be set up in the machine, if and when the specific programming factors of the business are quantified by management.

The concept of programming seems to add new life to planning, however successful planning has been in the past. Programming makes it possible to interrelate many objectives. Company executives will be able to consider the effect of many programs rather than only one. The programs can take into account top-level policies as well as plans for best use of the resources currently available.

The use of programming does not eliminate the need for competent managerial judgment at lower levels. In many cases a program can only set an objective and outline the way to reach it. The local manager or foreman must still work out the details, such as the approach to take to a particular customer or the rate to run a machine if the raw material is off-standard.

Programming makes it possible to reexamine and evaluate concepts such as decentralization. It will provide for the delegation of certain decisions as well as establish a better means of setting standards, variations from which will let top management know how the decentralized units are doing. At the same time, programming will emphasize the need for centralized consideration of the over-all objectives.

However, there are many limitations which will have to be overcome before this concept of programming can become effective. Mathematical programming is not a cure-all which can replace management judgment at all levels. Currently available tools are only useful for particular types of programming, usually where costs or revenues can be seen as proportional to volume.

Even if new tools are developed, the type of data currently gathered by business will have to be changed. In the past, accounting data were the major source of facts. Newer methods of programming will also rely upon engineering data, cost estimates, production quality, etc.

Too frequently it happens that important factors, such as the company organization and lines of communication, cannot be taken into account in present mathematical programming. The introduction of such factors into models requires design of new measuring units.

Despite their speed, electronic computers may be limited in their capacity to deal with the requirements of some programming problems. No matter how desirable the quantitative data, there may be no

economical means of handling the sheer quantity of arithmetical computations.

SCHEDULING

Once the best program has been selected, it is necessary to establish a precise, detailed, yet flexible means for carrying out the program. This can be called "scheduling."

Scheduling a program involves the physical details—quantities, qualities, locations, etc.—and the precise times when the various activities are to be completed, and by whom. In the past this has been accomplished by middle-management decisions, aided by the established policies, the systems-and-procedures manuals, and by the budgeting process.

Scheduling Requirements. Scheduling a program may involve the interrelationship of many factors. For example, if production is to be increased, the personnel department may have to add more people, the training department more instructors; capital assets may have to be increased, the accounting office may need a larger billing section, inventory policies may have to be changed, and so on. The new level of production may make it economical to increase subcontracting of particular kinds of work, so that available machines can be put to work on optimal operations.

Planning Factors. To schedule these changes requires the ability to estimate a large number of variables, to organize relationships to get the best use out of the available resources, as established by the program.

It can be taken for granted that programs will not always proceed as planned. Scheduling is prepared to answer questions as to what should be done when unexpected machine breakdown occurs, or when materials are not delivered, and so on. Through use of mathematical models for scheduling, the effects of rerouting production, delayed delivery schedules, and similar changes can be traced through to their ultimate effects on financial needs and profit expectation.

Organizational Goals. As indicated in the previous discussion of decentralization, large companies today are usually made up of several or many semi-independent organizational units. Each unit tends to have its own operational and professional objectives which differ in part from the company's over-all objectives. Scheduling, therefore, must keep the organization oriented in the right direction as well as

attempt to achieve the optimum local use of resources. This is equivalent to saying that scheduling is concerned with the basic organizational structure and with the fundamental factors of motivation at all levels, and with the operations in all divisions of a company.

Programming will be carried on under the assumption that a certain scheduled level of performance can be expected from each functional group. This implies that each group will know what is required of it, when and how the job is supposed to be done.

Information Flow. In addition to these original instructions, the functional groups need a flow of current information. The managers must be assured that work in preceding functions is being completed in time so that it will be ready for their schedule of operations, or they must be confident that new instructions will be forthcoming if it will not be ready.

Thus scheduling implies more than an original set of instructions. It calls for a means of rapid communication between the operating groups as well as between these groups and the scheduling managers. If the planning factors can be interrelated in "real time"—that is, as events happen rather than after they happen—then managers can administer their functions more confidently and more efficiently.

Development of the Scheduling Concept. Development of the scheduling concept will take place both in the decision-model process, which concerns optimum allocation of specific resources to specific activities, and in the operational stage, which concerns administration of the activities so that they will be performed at the specified times, using the allocated resources.

While some scheduling problems have been solved by the mathematical techniques, there still is no well-developed system which combines the various factors and produces the best schedule for the company as a whole, one that integrates with the program. Not only is there a growing awareness of the need for such a system, but a number of researchers are combining various tools in the hope that an integrated mathematical scheduling process will result.

Descriptive mathematical models have immediate applicability to the problem of stating the specific quantities and times at which specific resources are to be made available to specific activities. The scheduling of production and the control of inventories are suitable applications for such techniques. Mathematical simulation of processes often can be used to provide management with facts in a form which

facilitates decisions. Resulting savings often are substantial, and in many cases much larger than clerical cost savings can be.

To the extent that mathematical models can be developed to simulate the scheduling requirements, it will become more and more feasible to use electronics to make routine decisions. For example, employing a properly constructed model, a computer could be instructed to report inventory items which are below a minimum level, to examine the status of the need for those items in view of the current production schedule, and on that basis to determine whether a reorder should be placed. Given a currently maintained list of price quotes from suppliers, freight rates, time to deliver from suppliers' warehouses, etc., the computer could choose the best offer and print out a purchase order, ready for mailing.

An area which has been explored to some extent is that of establishing purchase requirements. Models have been developed which show the purchase needs quickly and economically, using computers to "explode" the bills of materials and to store the basic bills in an efficient manner. Learning curves have been used to set prices.

Scheduling requires evaluation of the various ways of meeting the programmed activities. It usually is possible to produce a given line of products in different ways, using different methods and different rates of production. The best way of meeting the program is, therefore, part of the scheduling process.

It appears that the growth of the scheduling concept will tend to change some managerial duties. Middle managers will be used less as processors of data, as people who make decisions largely according to rules and policies established by their superiors. They will be used more and more on borderline problems and on new situations which still call for human intelligence because they have not yet been successfully integrated into the model.

Also, middle managers will have a chance to reestablish personal contacts with customers and employees. These are contacts which the managers have been losing as they found themselves more and more isolated in their offices while trying to cope with the streams of detail that flow to them in present systems.

Mathematical models and electronic computers form a natural team for scheduling. Many scheduling models already developed are in a form well suited for solution by present computers. However, large-

size matrix models cannot be handled economically by present electronic systems. It is hoped that future developments in logical design of electronic systems will lead to a solution of this problem. This means that special-purpose electronic systems may be developed which are economically preferable for scheduling, a possibility which has serious implications for managements that are choosing an electronic installation.

As the mathematical requirements for scheduling are obtained, they will assist in establishing the specifications for electronic systems. In time, electronic systems should be used to help schedule the remaining clerical routines, to relate the schedule for one business function to that of others, and also to provide a tool to facilitate evaluation of both the program and the schedule.

FEEDBACK

Recording, processing, and transmitting information concerning operations in a manner and in time so managers can control the operations is called "feedback." Feedback is a method of determining which data are relevant, how they should be obtained, and how they should be presented in order to accomplish the purposes of programming and scheduling. As with most system concepts, it is misleading to describe parts of the situation without relating them to the whole. Figure 5 shows a simplified diagram of the role of feedback in the system concept under discussion.

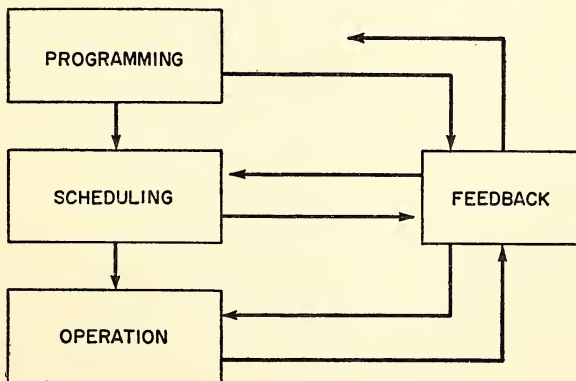


FIGURE 5

Many present systems attempt to provide information, such as cost variances, directly to the managers in charge of operations. But seldom can they do so in a form or in time so that action can be taken during the course of the operation. As a result, managers set up their own little reporting systems, in an attempt to remedy the deficiency.

Cost reports may be considered in schedule making and in planning, but they seldom are used in an integrated manner. It is too difficult, time-consuming, and expensive to trace through the system the many changes that result from rescheduling or replanning. Instead, resort is usually made to the "other things equal" assumption unless this is so obviously untrue that some recognition must be taken of the side effects of the changes.

For example, if costs are too high on one product, a decision to change the method of production, or to raise the selling price, or to cut back production, etc., rarely gives full consideration to all the effects that the action will have on current operations, on other products, and in areas other than production.

Feedback Requirements. The feedback concept emphasizes the importance of providing information which can be used to monitor both the program and the schedule. The monitoring can be automatic, as in the case of "automation" employing a servomechanism. It can be semiautomatic, employing dials, other instruments, or reports to initiate managerial or clerical reaction according to a fixed set of rules. Or it can be discretionary, as with an income statement given to a board of directors.

Relevancy of Data. Feedback involves rapid evaluation of data from various sources. It requires determination of which data should automatically actuate controls and which should be passed on to the human link in the planning and control system. The character of the determination will change with time; as more and more automation is introduced the decisions left to humans will decrease in number but increase in relative importance.

The problems involved in establishing a feedback system are considerable. As technology advances and as large organizations seek to decentralize, the problems increase. So far, the work done on a scientific basis by business in this field is inadequate. Pioneering has been led by groups such as those at the RAND Corporation, which have made laboratory studies of the way that information is sought and transmitted in complex organizations. The studies were made by teams

composed of mathematicians, statisticians, and psychologists, aided by neurologists and electronic engineers.

Illustration of Relevancy. The only area in business that has been explored in this way, even to a fair extent, has been the cost system. It has been recognized that information produced by a cost system should be useful and produced in an economical manner. But too often the cost system is oriented to providing figures that the accountant can use in costing sales and inventory, for published reports and tax purposes, with managerial uses provided only as a secondary feature. A more complete description of the factors that should be evaluated in developing a good cost system would include, as a minimum, such items as the need to provide information used in operating reports and financial reports, to value inventories, to fulfill accounting principle requirements, to meet tax or other governmental requirements, to provide a basis for scheduling and other action taking at various levels of management, and to aid in programming the future activities of the company.

Further, the data should be provided in a timely and economical manner. This means that clerical and other related processing costs should be at a minimum, that data should arrive in time so they can be used for control purposes, that the data should be consistent, that the cost system should avoid duplication of other data systems, and that the reports should provide maximum communication consistent with the amount of time for reading warranted by the need for the data, and so on.

Data for cost accounting usually must be recorded as the products flow, otherwise the probability of incomplete recording is high. The criteria for selection of the proper cost centers seldom are established on a scientific basis, although, as indicated earlier, procedures studies have produced some advances in this area. But leading texts and handbooks still tend to define cost centers in terms of the need to apply direct costs and overhead to the product as it passes through certain groups of equipment. This computation not only is costly, but the overhead application in many cases is rarely of any consequence as far as managerial control of the operation is concerned. On the other hand, since the costs derived tend to be considered as "actual costs," businessmen often try to price sales in the light of the computed cost figure.

Cost systems often become even more complicated and cumbersome

when many of the costs are incurred at so-called "nonproductive" cost centers. The amount of computations may become tremendous. In the attempt to trace the costs through the products, several companies have used large-scale computers for cost distributions.

It is evident that a cost system has several dimensions—financial-statement product costing, responsibility costing, project or "purpose" costing, etc. Joel Dean, in *Managerial Economics*, has given an extended discussion of the different types of costs that may be of consequence for different types of decisions. Among these are: traceable or direct costs as opposed to common or indirect costs, variable costs as opposed to constant costs, book costs as opposed to out-of-pocket costs, incremental costs as opposed to sunk costs, escapable costs as opposed to unavoidable costs, controllable costs as opposed to noncontrollable costs, opportunity costs as opposed to outlay costs, past costs as opposed to future costs, short-run as opposed to long-run costs, and historical costs as opposed to replacement costs.

Since management has not been able to obtain cost data at will, in the manner best suited for a particular decision, many executives have tended to concentrate on one type of cost and encouraged their staff analysts to develop methods for determining that one particular type. Some management-consulting firms have built reputations through concentrating on one or a few of these cost types.

The one which seems to be favored at present is the cost-volume relationship, shown through analysis of fixed and variable costs as "break-even" charts, or "P-V" relationships. These have proved helpful in many situations, and it is not expected that they will be abandoned. Rather, their use will be augmented by making available more of the several possible ways of analyzing costs.

Generally speaking, data should go first to the lowest level of the organization, to the operating men. If higher levels get the reports first, they will try to take corrective action before the lower levels know the score, which inevitably creates friction. The "black book" system will be revived for protective purposes.

Timeliness. Since programming is concerned with such matters as the optimum allocation of resources, as a rule the feedback for this purpose need be neither overprecise nor rapid. Programming plans are seldom developed overnight. A decision to enter a new field with a new product line may require long periods of research, lengthy negotiations with new distributors, or drawn-out negotiations for the

purchase of going concerns. And since the program is judged by such standards as rates of return, substantial rounding off of figures or some imprecision of estimates may be quite satisfactory.

Scheduling requires faster feedback. If a suitable model has been developed, it may be possible to reschedule at short notice in order to meet the exigencies caused by breakdowns, supply failures, short-notice customer demands, and so on. The frequency of such emergencies will vary greatly from business to business; a job-order shop will reschedule more frequently than a firm with a few standard products for which the demand is relatively steady. Nevertheless, even where the product is seldom changed, research groups have been studying the possibility of improved scheduling of production and warehouse distribution as a direct reflection of current sales activity. Cross-country communication networks have been established.

The feedback to the operating managers obviously must be immediate, for optimum control. If possible, it should indicate the immediate future trend. Managers would like to have information as current as the minute-to-minute rate of sales in various departments of a store, with the implications for sales the rest of the day and week, if this could be obtained economically. A production manager would like to have a constant flow of information on the movement of partly finished materials from other departments to his, and on the flow of production past the key check points of his operation.

In many cases managers attempt to achieve this goal now by rough-cut means. Sales managers "walk" the store, and through experience are often able to gauge sales activity very closely. Production managers watch bottlenecks, such as a press past which most of their production flows. They are able to estimate how the line is doing through observation of the work waiting at the bottleneck.

A good feedback system would achieve the same results, as a regular part of the procedure.

The speed demanded becomes greater as one goes from programming through scheduling to operating needs. At the same time the amount of information required tends first to rise, then to decrease. A few key figures, reported rapidly, often are enough to tell the operating manager how his shop is getting along.

Reporting. While feedback reports to operating managers deal primarily with immediately current activities and short-range forecasts, those for scheduling require some consideration of forecasts for

longer periods. Reports for programming are concerned almost entirely with such estimates, which may be for years ahead.

Sometimes the programming needs for data are said to be like looking at the organization as though it were a system of flows to and from a series of "black boxes," without worrying too much about what goes on inside the black boxes. This concept may be helpful if it is remembered that the "flows" include personal relations, attitudes, and so on, as well as products and dollars. Scheduling worries more about the inside of the black boxes and the timing of the flows.

Accuracy. Another difference deals with the relative accuracy of the data reported. In many cases it is enough for the operating manager to know that something is going off schedule and an indication of how much he should do to correct the aberration. If the variance is fairly sizable, it will probably have to go out of his hands anyhow, in the sense that rescheduling may be called for. On the other hand, programming may be carried on quite successfully with estimates that are only expected to lie within a range of several percentage points. Many sales managers, for example, would be glad to settle for the assurance that a sales forecast would be within five per cent of accuracy almost all the time, especially if they also knew that the system of feedback would indicate how the forecast should be changed as current sales reports start to flow in.

Scheduling requires more accurate measurements. Such items as the current status of the operations are needed in order to check out the schedule. For example, if the count of parts is inaccurate and the actual amount too low, then completed items cannot be assembled in the scheduled quantity.

Development of the Feedback Concept. In recent years much publicity has been given to the concept of management by exception. While this has frequently proved to be an improvement over previous systems in cutting down the detail brought to the attention of managers, a new difficulty has arisen. In his attempt to get the operation back to standard, too often the manager overcompensates or undercompensates for the variation. A classic example is the attempt to keep costs in line by the cutting of advertising allowances when sales fall.

The problem not only is to report that an operation is out of line, but to show the relative degree to which it is out of line, together with an indication of the amount of corrective action which should be taken. At present this corrective action usually is decided upon by the man-

ager largely on the basis of his accumulated personal experience. As more is learned about the factors which throw operations out of line, these corrections can be incorporated into a feedback system so that they will become more and more automatic.

This increase in understanding has already started at the operating level, with automation. So far, little knowledge exists with which to set standards at the top-management level. As indicated earlier in this chapter, a rate of return on investment has been used to some extent for measuring top-management performance, but the shortcomings of the method are such that the need exists for more scientific standards to be used for this appraisal.

Feedback puts prime emphasis on the usability of information. This means that the information not only must be what the managers can understand, but also it must be directly relevant to their individual needs and arrive in time for them to use it for current decisions. For this reason, as indicated at the start of this section, feedback can be studied only in the light of programming and scheduling concepts.

If accounting is to be relied on to provide the data for scheduling, some changes in present systems usually will be required. For accounting to provide the necessary accuracy, the process usually followed at present calls for so many checks and rehandling of the figures that the data are obsolete when they arrive. If the data can be measured by counters, either mechanical or electronic, and transmitted along electrical circuits, or through the use of such devices as industrial TV, then the scheduling process will be aided considerably.

Reports of data in tabular or chart form may be suitable for programming, but inadequate for scheduling. Middle management has to relate data to much other specific information in order to make a decision. If the data can be brought together and processed in terms of a mathematical model, the decisions obviously would be greatly facilitated. The feedback would automatically provide a constant testing of a suggested course of action.

Feedback is intimately concerned with both the organization structure and the method of reporting to each level. Although management today frequently feels that it receives too many reports, in almost every instance a justification can be found for supplying the information because of some type of decision which occasionally has to be made. Only if the manager could be sure that the particular bit of information found on an infrequently used report would be readily forthcoming

ing on requests would he cheerfully agree to elimination of the regular report.

As a rule it probably will be found that the nearer the operating level, the more the reports are concerned with physical quantities, while top-level programs will more often be in dollar terms. Schedules tend to be primarily physical, as they pertain to departments like production, but may take on dollar aspects in all areas. Some schedules may be wholly in dollars, however, as in forecasting cash requirements.

It should be apparent that electronic systems, and use of mathematical models, will be of considerable assistance in providing better feedbacks. Speed, accuracy, mathematical manipulation, condensation, reporting of exceptions, and so on, are precisely the sorts of abilities they offer. Since computers can be instructed to handle data in a variety of ways, it is possible to arrange for different types of reports to be made to different levels of management, starting from the same set of original data. Such systems will be discussed in Chapter 9.

SUMMARY

Programming, Scheduling, and Feedback. Electronics has already been recognized as a means of improving the communications which are necessary for present systems of planning and control. Don G. Mitchell, chairman of the board of directors at Sylvania Electric Products, has stated in a speech describing new electronic developments in the field of communication:

The many benefits of this [decentralization] policy include far-greater flexibility in operations, faster action, new and better ideas, and greater efficiencies all along the line. This obviously creates quite a problem in communication—so that the decentralized plants will not be operating in separate vacuums, like electrons that have escaped the force binding them to the nucleus of an atom.

Although the separate plants are decentralized in authority and responsibility, and are given a job to do and permitted to do it, they are nevertheless part of a whole. You can carry "state's rights" too far in industry. To assure coordination—not interference with a local manager's prerogatives—companywide information must be gathered speedily and delivered to those in managerial and policy-making positions in time to do something about it. The accountants call this integrated data proc-

essing—which is a fancy way to describe the process of recording and processing day-to-day information, and presenting it rapidly in summarized form so that management can act while the situation is fresh.

Here again is a major opportunity for the accountant: helping to develop this system of high-speed communication, deciding what information is required, and what should be done to that information to obtain coordinated reports. Those who have had experience with decentralized companies may wonder if such a system would not act to the detriment of the operating man, and tend to centralize controls. It not only would not destroy decentralization, but would foster it by supplying the operating organization with the required information, and the top management with the data it needs.

The ways in which electronics can aid in this effort to achieve faster communication have already been indicated to some extent in earlier chapters.

In addition, some of the newer mathematical tools can help develop methods to judge more rapidly the effectiveness of various alternative management plans. These methods can take into consideration many different ways of doing things, ways which explicitly introduce alternative courses of actions. The analysts can evaluate the objectives of the company—profit and otherwise—and help select that alternative which will result in the best course of action.

As Henderson and Schlaifer declared in the *Harvard Business Review*:

In recent years mathematicians have worked out a number of new procedures which make it possible for management to solve a wide variety of important company problems much faster, more easily, and more accurately than ever before. These procedures have sometimes been called “linear programming.” Actually “linear” describes only one group of them; “mathematical programming” is a more suitable title.

Mathematical programming is not just an improved way of getting certain jobs done. It is in every sense a *new* way. It is new in the sense that double-entry bookkeeping was new in the Middle Ages, or that mechanization in the office was new earlier in this century, or that automation in the plant is new today. Because mathematical programming is so new, the gap between the scientist and the businessman—between the researcher and the user—has not yet been bridged. Mathematical programming has made the news, but few businessmen really understand how it can be of use in their own companies.

The purpose of management planning and control is not merely to speed communication, to reduce clerical costs, or to establish the decision rules now made by middle management. The purpose is to achieve the full range of the company's objectives.

Many executives now believe that the key to full achievement will be the adoption of a new conceptual framework. It is their belief that only by a change in thinking can the gap be bridged between the electronics engineer, the mathematician, and the businessman.

CHAPTER NINE

Integrated Business Systems

Whether a company has started with a single application for an electronic system or with a study of management planning and control, the result usually has been recognition of the need for extending the work. For example, applications of electronic computers to payroll data processing have been expanded to include labor reports, cost accounting, etc. Studies of the scheduling aspect of the management planning and control system have led to the need for feedback.

The term "integrated business system" combines the concepts of business data handling and of programming, scheduling, and feedback. In this sense it covers both the electronic data-processing system and the system of management planning and control. Integration means that each is developed in full recognition of the capabilities and requirements of the other.

An integrated business system links the event that originates an item of information with the events that occur wherever and whenever someone uses this information. The data flows can be traced directly from the point of original record until they reach processing or decision points. The flows then take one of two forms—combining or branching. These forms can be represented as follows:

1. *Combining:*

Event → Original record → Information flow
Storage of information → Information flow — } → Processing → Report

Typically, a report combines items of information, of which one may be from storage. The storage item may be as simple as the product or employee code number identifying the object or person to whom the event occurred. Combining also may bring to-

gether two original records, or two items from storage. (A report is a form of storage, in the sense considered here.)

2. *Branching:*

Report $\rightarrow$ Information analysis $\rightarrow$ Decision $\rightarrow$ $\left\{ \begin{array}{l} \rightarrow \text{Choice 1} \rightarrow \text{Event} \\ \rightarrow \text{Choice 2} \rightarrow \text{Event} \end{array} \right.$

Branching signifies the use of data by a manager to make a choice between alternatives. His decision programs or schedules a new event.

In the typical business situation several items of information usually are combined on one report. Or, a choice is made from more than two alternatives. By analyzing business operations into these two basic forms they can be seen in their fundamental aspects. When these have been established, the elements can be synthesized into an integrated business system.

THE INTEGRATED BUSINESS SYSTEM CONCEPT

An integrated business system can be viewed as a communication process. Transactions occur, are recorded, and the record communicated or stored. Decisions are made by managers who, knowing the established policies of the company, consider the facts presented to them. When an individual manager makes a decision, he transmits information to others in the organization. They act, or use the information in turn as the basis for their own decision making.

For example, when a machine breaks down, the worker usually informs the foreman. The foreman must make a decision from among a number of alternatives. He may relocate the work. He may request immediate repairs from the maintenance department. If the breakdown is sufficiently serious, the foreman will notify the superintendent and the scheduling office. Someone will then reschedule. Meanwhile maintenance must decide whom to send on the repair job, giving consideration to other calls for their services. Later, the engineering department may collect data as to frequency of machine breakdown. A report may be prepared for consideration by managers, who may decide to replace the machine.

In an integrated business system, three activities can be distinguished:

1. Information flow, direct transfer.
2. Information process, report combining.
3. Information analysis, decision branching.

The first part of this chapter will discuss the problems involved in direct transfer of information. Information analysis, decision branching, was covered in Chapters 6, 7, and 8 and will only be touched on here. The latter part of this chapter deals with the combining process and report creation, the integrated data-processing system.

DIRECT TRANSFER OF INFORMATION

A business is constantly transferring information from one place to another, starting with a number of points of origin and following through to a variety of end-users. Viewing this process objectively, it can be broken down into these basic elements:

1. Originator of the information.
2. The physical means of communication and the channel the message follows.
3. Symbols used to convey the information (language, numbers, etc.)
4. The message.
5. User of the information, or storage point.
6. Continuation of the process, in the sense that the user originates a new message, or the information later is drawn from storage.

Communication often follows "loops," since some of it returns to the originator. Perhaps the return is only a notice that his message has been received. Often there is additional information in the form of instruction, or there may be variance comparisons with stored information.

There always should be additional information flowing at some time from each user. Unless the recipient eventually takes some sort of reportable action, the original information must be considered useless. The communication process has failed.

Because of their interrelationship, these basic elements will be discussed in groups, rather than as separate items.

Communication, Symbols. There are many kinds of information channels. People talk directly, use the telephone, or use other media.

They send written reports, which often go in multiple copies to several parties. The information may be transferred in whole or in part through several levels of management.

The paths followed may be formal or informal. By "formal" communication is meant the channels established in manuals, which describe the type of information that shall be reported, who is to give it to whom, when it is to be reported, and so on. Standard forms usually are prescribed. The formal communication plan is closely related to the organization chart.

Although a company frequently makes an effort to increase the relative percentage of information that is formally recorded rather than relying on informal communications, nevertheless the formal system has limitations. Not all contingencies or needs can be determined beforehand. Written reports may not impart a "feel" for a problem.

It is hard to estimate how much of the information flow in a business moves through personal contacts in conferences, at lunch, in car-ride pools, at the water cooler, over the telephone, and so on. Some managers believe that it is well over half, and a few make it even higher. Some boast that they never read a written report.

The electronic system can handle both formal and informal communication. It may be used to increase the percentage of the total information that is formally communicated. By making the formal communications network speedy and obviously superior to the informal one, it will tend to monitor and replace the less efficient medium.

There are numerous drawbacks to the informal system, not the least of which is that it is inaccurate, especially if more than one transfer is involved. Anyone who has traced a bit of information as it passes verbally and informally from person to person knows how it can become distorted—figures change, and sometimes the meaning is entirely reversed. The successes of the grapevine tend to be remembered, and its many failures forgotten.

However, the informal system is hard to displace and impossible to eliminate. Another possible improvement lies in making the informal system more direct, e.g., through industrial TV.

This means that the barriers to formal communication must be objectively examined and provision to overcome them incorporated as far as possible into the system itself. Among these barriers, the following can be distinguished as fundamental: (1) semantic differences, (2) different frames of reference, (3) status distance, (4) geographical

distance, (5) need for self-protection, and (6) pressure of other work.

1. *Semantic Differences.* Although the problem is as old as time, it is only in recent years that businessmen have discovered the usefulness of the scientific attention which has been directed to the semantic differences that exist within a language. An industrial combination is made up of a number of functional groupings. Each function—sales, production, finance, purchasing, product engineering, research and development, and so on—has its own set of terms, its own slang, and its own attitudes. Moreover, the problem of communication can exist within a function, when a small group develops an interest in a new field foreign to the experience of the majority. “Linear programming” has occasioned this sort of difficulty in a number of firms.

Perhaps even more vital is the fact that all humans must use language and mathematical symbols with which to perform the act of thinking itself before anything can be communicated. Since all of us absorb our knowledge of language in many ways, the result has been that our very thinking processes reflect many unscientific beliefs and prejudices. These prejudices concern not only such general topics as religion and race, but more fundamental concepts such as the structure of language itself—the meaning to be attributed to the whole class of nouns, the significance of the grammatical construction of sentences, logical analysis, and so on. A number of books have appeared which indicate the nature of these difficulties, such as Ogden and Richards’ *The Meaning of Meaning*, Percy Bridgman’s *The Logic of Modern Physics*, Korzybski’s *Science and Sanity* (the latter popularized in several well-known works by Stuart Chase), and several publications by Rudolf Carnap.

A thought expressed in symbols can only bear a relation to reality; it can never be the reality itself. A symbolic representation of this relationship is all that can be communicated. The communicated idea can hardly be less fuzzy than the thought that originated in the first observer, and almost inevitably something is lost each time the message is transferred.

The importance of this problem has been hidden by concentration on other difficulties in the communication process, such as the overcoming of distance. But the communication problem will not be appreciably lessened without consideration of this basic difficulty. Even if two businessmen live together, have most of their major interests in common, work together on projects, like each other, and so on, they still may not be able to communicate effectively.

While we are far from the solution of this difficulty, it is a major accomplishment even to recognize the nature of the problem. Considerable resources are now being devoted by universities to the study of semantics, and business has at least become aware of the need for further scientific investigation in this area.

2. *Frame of Reference.* Unfortunately the basic language barrier is only the beginning of the problem. Although the original statement may be clearly and correctly expressed, in so far as both the originator and recipient are concerned, each recipient has a different environment, a different "frame of reference," and even though he "understands" the communication he will never react to the information exactly as the first party did. Too often, this difference will result in substantial distortion.

For example, in one company a production department thought that the purchasing department was not providing necessary parts on time. The belief persisted in spite of the information to the contrary reported on a parts shortage list. The production department's reaction to the situation was that purchasing simply didn't understand their problem.

The same set of facts may be interpreted quite differently by various groups. In many companies, when sales fall off, the production department may want to increase output in order to lower unit costs so prices can be lowered, the treasurer may want to curtail production so as to conserve cash, the sales department may want to increase the advertising budget, while the general manager may consider dropping the line . . . and so on. Knowing this diversity of interpretation, departments frequently conceal or delay transmission of information. This point deserves separate discussion (see point 5).

3. *Status Difference.* Effectiveness of communication in an organization frequently bears a direct relationship to the difference in status between the parties involved. Managers and workers on approximately the same level often communicate freely. Where status differs, communication often is better downward than upward. Devices such as suggestion boxes are useful but makeshift solutions to this problem.

The personality of the executive has considerable influence on this situation. Executives who "walk their shop," keep their desks out with those of workers on lower levels of authority, or maintain "open-door" policies in their office can affect the informal communication pattern considerably. However, the process is time-consuming and is not always desirable.

Formal communication between levels is difficult to influence. Despite the old saying, bad news does not travel fast in an upward direction unless deliberate attention is given to making sure that it will do this. A major function of the internal audit staff in many companies is to minimize attempted distortion or deliberate falsification of reports.

As an example, the "idle time" concept is highly thought of in textbooks, but in practice it is difficult to monitor because of obvious connotations. The effort to avoid such a report may lead to considerable distortion. In one large company the present practice of a certain group is to report all effort 4 days late, so that idle periods can be covered up.

Incidentally, this practice has been uncovered in Russia, where a few division leaders have set their yearly quotas at the level of the previous year's production. They then reported a year late, holding over net balances in inventory.

4. *Geographical Distance.* Decentralization of management and expansion of facilities in various parts of the country or the world have made the coverage of distance an important factor in communication. This part of the problem, in many respects, has been solved the best, perhaps because it appears so obviously as a problem. Some executives have learned "to live on the telephone" almost literally.

Nevertheless communication of large volumes of information over long distances is still expensive and not always as effective as it should be. Companies still find it worthwhile to hold meetings of their salesmen, and of various levels of the executives, to supply the spark that is lacking in formal communication.

5. *Self-protection.* As indicated earlier, if given the opportunity, people usually slant reports so as to minimize information which puts them in a bad light. Knowing this, many executives automatically increase the significance attached to any piece of bad news and tend to discount good news. The persons who report become aware of this, and so they increase the degree of minimization of bad news, leading to further reactions by executives, until the matter gets out of hand.

There is no way to eliminate this human tendency, but some attempt must be made to stabilize the influence so that it is held within tolerable limits. An effort to bypass the human reporter wherever possible, through use of automatic recording devices, is being made and will probably increase in the future.

The points of information origin must be chosen with considerable

care. Safeguards must be built into the system to make sure that the operating personnel do not slant their efforts toward the check points and avoid fulfilling other obligations that supposedly were to be accomplished simultaneously. A simple example would be the efforts of production men to get items past inspection, regardless of the other consequences of their efforts.

6. *Work Pressure.* Most executives are judged by the quantity of work they turn out and not by the quantity or quality of the information they originate. (An exception may be special reports which they occasionally make for superiors.) Communication may be slighted. As work pressure increases, communication is delegated more and more to clerical staffs, with a minimum of interpretive material added by the executives.

In some firms the situation becomes so bad that it is formally recognized. Representatives of the data-processing departments, under the controller, are sent in.

Recording may be in the hands of an outside group, but unless their efforts are trusted by the operators the resulting reports will cause nothing but friction. Some firms have attempted to solve this by having the recorders responsible to both the operating manager and the functional head of accounting. In any case, the matter remains a problem, correspondingly greater as work pressure mounts.

Originator, Message, and User. The design of an integrated business system should consider simultaneously the position of the originator of information, the form of the message, and the need of the user. This is a difficult task.

The closest approach in present practice to the type of analysis which is required is found in studies of decentralization. An example is the investigation undertaken by H. A. Simon, G. Kozmetsky, H. Guetzkow, and G. Tyndall for the Controllershship Foundation (published in 1954 as *Centralization vs. Decentralization*).

This study defined an administrative organization as centralized to the extent that decisions are made at relatively high levels in the organization, and decentralized to the extent that there are important delegations of discretion and decision making from higher to lower levels. After separating management's use of figures into three categories—(1) score card, (2) attention direction, and (3) problem solving—the study found that the three different uses are not of the same importance to executives in different parts of the operating organization. At all

levels of management, score-card and attention-directing uses of information are more frequent than problem-solving uses. Problem-solving uses of accounting data are encountered most frequently in staff units that have responsibility for making special studies.

Because of these differences in the persons to whom the information is directed, and in the content of the information, a controller's department that is well organized to provide one service may not be well organized to provide another. The authors concluded that for score card and attention directing it is important for the controller's department to develop a close and direct relationship between accounting and operating personnel.

Other authors have gone so far as to advocate completely autonomous reporting groups, often comprised of only one or a few people, each reporting directly to and for an operating manager.

For problem solving there are two possible solutions. One is for the controller's department to make more elaborate reports so that the information needed will usually be found on the regular reports. The other is to devote more attention to special analyses that go back to the raw data, to build up specific figures that are needed to answer specific questions. The authors of the controllership study recommended the latter course.

Since this study was based upon investigation of actual operations in a number of companies, it is evident that some businessmen are already moving in the direction of fitting the data-processing system more directly to the needs of the users. If score-card and attention-getting data are reported as gathered directly to managers, and if problem-solving data are developed from raw data by special staff groups, it is evident that for the first user there would tend to be reporting of data only as required. The "time-schedule" problem of data processing would be minimized.

However, if the data must be used for several purposes, as is usually the case (for payroll, etc.), the duplicate processing required often becomes expensive. There are a number of ways that this "message" problem can be relieved.

The simplest is to report the data in physical terms where possible. Dollarizing the data is time-consuming, expensive, and frequently unnecessary. Some items, such as manpower status, may be handled best by clerks reporting directly to superintendents, as straightforward counts.

Where more complicated reports are necessary, such as of variances, it still may be possible to provide meaningful data as physical counts. If accumulations through time are needed, then the use of counters and of electronic systems may be indicated. However, this raises serious problems concerning the location of the equipment. Some companies are following their decentralized pattern, and ordering several smaller sized computers for each of their branches; some are considering or have already ordered one or a few of the large-scale computers for their centralized record-keeping.

Use of the computer, with its ability to process data rapidly, should not be permitted to encourage managers to ask for data they do not need. In many cases, if a model can be constructed of a particular operation, the manager can operate in terms of key inputs, outputs, and variables in his model.

Eventually, as a number of these models of parts of the system are developed, the time may come when development of the over-all model of the system can be attempted, with reasonable hope of success.

Information Analysis. Little work has yet been done on the study of the integrated business system so as to incorporate decision making—"branching."

The interrelationships of decision making are difficult to establish, especially in view of the large part that informal communication now plays in the process. There have been some studies in this field, such as the work at RAND, at the University of Michigan, and at the Harvard Business School on the functioning of committees. The Ford Foundation has granted Carnegie Institute of Technology a substantial sum for basic research in this area.

Another difficulty in modeling the decision process is to indicate the role played by factors external to the company.

Some work has been done in production control, employing both mathematics and electronics. Tentative models of systems have been constructed, but they have not been tested, nor has there been much attempt to integrate them with the rest of the system.

Development of fully integrated business systems so as to provide formally for decision-making and the data-handling system is dependent upon research of the type described in Chapters 6, 7, and 8. Meanwhile, present electronic applications usually employ the "combining" process.

Many problems must yet be solved in order to develop integrated

systems for the combining aspect of the system—especially for summarization and reporting of information. Solution of these data-handling problems is a prerequisite for eventual combination with branching systems.

Development of the data-handling system for programming, scheduling, and feedback will require precise determination of managerial requirements for decision information. It must take into account the action that flows from information, the manner in which the formal organization is structured, the informal organization of the company, and so on.

Integration of this data-handling system with programming, scheduling, and feedback must wait for the future. Equipment—electronic or electromechanical—to implement a fully integrated business system is not yet available. But the direction that developments are taking can be foreseen, and changes can be made in advance which allow for partial adoption of the new methods and techniques. This preparation will be aided by the fact that electronics and mathematics can be used right now to cut clerical costs, to aid in making better decisions, to study ways of organizing effectively, and for other similar purposes.

Many companies already have taken the first step toward fully integrated business systems by installing integrated data-handling systems. Therefore the remainder of this chapter will be devoted primarily to discussion of the combining process.

PREPARATION FOR INTEGRATED DATA HANDLING

The problems created by inadequate business data-handling systems are well known. They arise from such items as the following:

1. Useless and outmoded communications and reports.
2. Duplicate records, created and maintained in the same organization.
3. Storage of elaborate records to support claims of accomplishment, or in anticipation of questions that may never be asked.
4. Excessive analyses and statistics, employed as substitutes for individual judgment.
5. Poorly designed records which are basically necessary, but are encumbered with extraneous and costly information of little use to anyone.

6. Information assembled to satisfy individual curiosity, having no practical value.

Most companies continuously study their organization, their information needs and methods of handling, processing, and reporting data. These studies have resulted in measurable economies and a degree of control over methods employed in the clerical, accounting, and administrative services.

The approach in these studies usually has been in terms of "the questioning attitude." Analysts have worried about such things as the proper way to view the functions involved, the proper way to categorize and relate the operating supervisors, the documents and reports, and so on. Or, time studies have been made and standards established, much like those found in the factory. Flow charts have been prepared to help determine the best way to process documents.

In most cases the recommendations of analysts have had to be "sold" individually to each level of the supervision and management concerned. As a result, the recommendations have often tended to become shaped so as to facilitate this persuasion.

In an integrated data-handling study, on the other hand, the over-all objective is not merely to reduce paper-work costs but rather:

1. To increase management effectiveness through analysis of the information needed for decision making and through the means of processing it in a timely fashion.
2. To establish a continuous system, one which promotes greater coordination throughout the company—an interdepartmental point of view.

There has been a tendency for business-system analysts to become diverted by the cost-reduction opportunities. Often they lose sight of these major purposes. Sometimes they forget that the best solution may be to stop collecting the data, rather than to process it better and faster.

The availability of an electronic computer does not solve these problems. In fact, it can compound the difficulties. The speed, versatility, and logical capabilities of electronic equipment enable it to produce almost limitless reports. But an increase in the volume of the reports does not ensure better decisions.

Voluminous detailed reports can confuse or overwhelm the recipients. Some executives will fail to act because they deliberately choose to ignore the mountain of facts. Others will become uncertain because of the excessive amount of time required to sort out the significant data.

On the other hand, elimination of needed information, through over-emphasis on clerical cost reduction, can hamper executive effectiveness to an equal if not greater degree.

Electronic computers are an aid to those who wish to integrate data-handling business systems. But by themselves they cannot determine when a report is needed, or if it is useless and outmoded, or that duplication exists as between two organizations. Computers are tools which can be used to achieve integration, but the user must first establish conceptually the system of planning and control. Then he can design the data-handling system and fit the electronic devices to it. The reverse approach, fitting the electronic tool into existing data routines, is almost certain to achieve something less than an optimum result.

Adoption of some concept, such as that of programming, scheduling, and feedback, is basic. The establishment of some fundamental concept is necessary to structure the system study. Only in this way can consideration be given to all end purposes of the data-processing system—not only to the need to prepare financial reports for stockholders, bankers, tax returns, and so on, but also to the specific needs of various levels of operating managers.

Integrated Data-handling Studies—Experience to Date. There are two major classes of integrated business data-handling systems:

1. *Integration of the form of source data.* U.S. Steel's "Common Language" Project is an example. Du Pont, SKF, and others are also developing their own systems. These try to integrate the source data into "one common form"—a punched tape or magnetic tape—so that it can be used by different machines and for various functions, e.g., cost accounting, production control, billing, etc., without retranscription.
2. *Geographical integration.* Information generated by various geographical units—plants, sales offices, warehouses—are integrated into the business-data system. Alcoa has sales offices transmit to Pittsburgh, by teletype on punched-paper tape, all the sales orders received. Pittsburgh in turn assigns and transmits the orders to various plants, all within one day.

Most companies have confined their efforts to part of the first class of problems—to integration of data requirements for a particular function. Some have also undertaken the second class—geographical integration. The number is growing rapidly.

Most current studies tend to emphasize determination of the best equipment, and only secondarily the need for systems procedure redesign. However, some companies, like du Pont, SKF, Alcoa, and U.S. Steel, have undertaken major revisions of their data systems. U.S. Steel's integrated data program stresses three major objectives:

1. Data should be recorded mechanically at the point of origination.
2. Data should be processed mechanically without need for manual recopying of the information.
3. The data system should be integrated to prepare for subsequent application of electronic equipment.

In order to accomplish these objectives, U.S. Steel and other companies have selected equipment on which they record the original data in a form that can be handled both by the communication equipment which transmits the data and by the computational equipment which processes it. U.S. Steel selected typewriters, at the point of origin, that produce five-channel punched-paper tape. Five-channel paper tape can be fed directly into teletypewriters. Data originally recorded at a branch plant or sales office, therefore, can be sent to the central office without retyping. At the receiving end a receiving teletypewriter prepares a five-channel paper tape automatically. The new tape is used to produce a report on another typewriter, or is sent to the computing section, where a special machine can produce punched cards or transfer the data to magnetic tapes. Figure 6 illustrates such a system for integrating sales-order procedure.

Conversion to Integrated Data Handling. Experience has shown that in order to establish an integrated system the old data system usually must be changed. The conversion requires many modifications to existing forms and procedures. U.S. Steel, for example, completely redesigned many of its forms.

The new systems also require that it be possible to have exact reproduction of forms, as transmitted at the point of origin. In some companies various sales offices or branch plants now use somewhat different forms and reports. These must be made uniform.

Also, communication by teletype or leased phone lines is expensive.

Every redundant word that can be eliminated will save transmission costs. In one company a recent study of business forms resulted in reducing the amount of written information by 40 per cent. Substantial savings resulted from elimination of unessential data, from "whole dollar" accounting, and from standardized coding of the data.

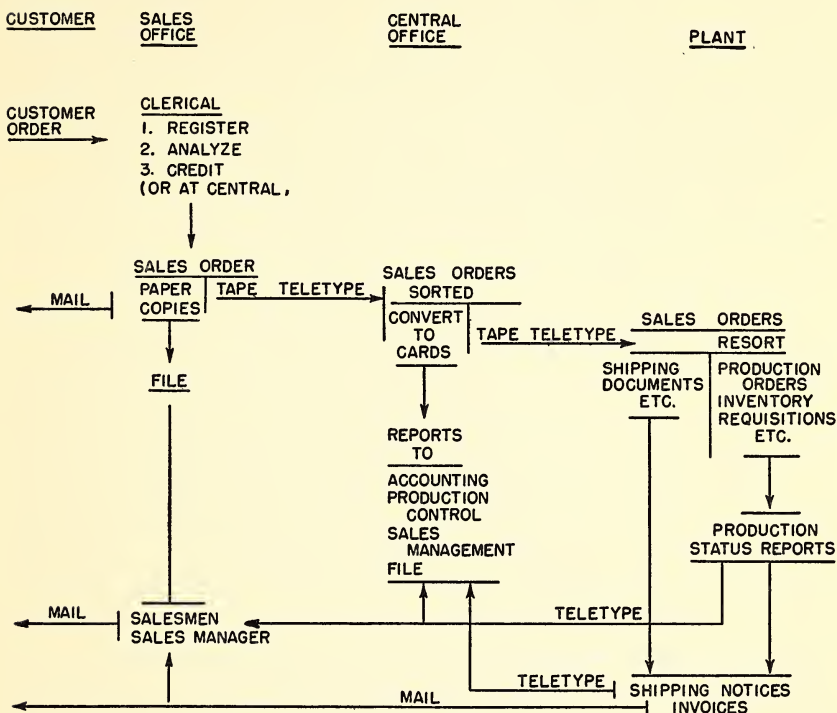


FIGURE 6

When data are to be received and transcribed on common media, other procedures usually must be changed. The tape must be filed. Checks must be provided to ensure that transmitted data will be accurate, and that data do not get lost, or are not held up unduly, etc.

Integrated codes are required. Sales orders, package identification, shipping tags, production orders, and sales invoices must be coded in a manner which provides for detailed identification and checking. The code should be designed so as to facilitate sorting by the sales department, the accounting department, and so on. Most companies have approached this problem by coding one procedure at a time. Installation of codes which will facilitate integrated data processing

is a major project. So far it has been given only theoretical attention by most companies.

In preparing for a computer, it has been found that special conditions in the data should be assigned definite codes so that their use by the computer will be efficient. Records ordinarily reflect a great variety of conditions. The computer must be warned, by means of the code, which condition is present before it can select the proper procedure.

If the system designer is not careful at this point, he can force the computer to make lengthy searches before it takes a useful step. Even at best there will be many occasions when the electronic system spends more time finding out what ought to be done than actually doing it.

Economic Results of Conversion. Initial applications of partly integrated systems have had two important results: reduction in clerical labor, and reduction in time of processing data.

The investment in equipment and in changing the systems has been substantial. However, systems studies have paid for themselves. In one company, integration of sales orders, production planning, and inventory control already has resulted in an annual savings of over a million dollars. Equipment (not electronic) was repaid in four months. Before this could be achieved, more than two years of study was required. The time was necessary in order to evaluate the needs, program the system and procedure improvements, establish an integrated code, redesign the form and reports, and to select and install appropriate equipment.

Integration with Electronics. Some companies have adopted a program of gradual conversion to electronics. They believe that they can integrate further developments in electronic systems, or automation, with their present methods. However, before their electronic systems can make full use of common media, such as paper tape, they often require special devices, such as paper tape to magnetic tape, or paper tape to card converters.

Some transmitting devices currently under development may not require tapes. They can be actuated by other electronic or optical means. They may operate much more efficiently than present systems. For this reason, even the most advanced installations try to remain flexible.

Electronic systems can perform operations not possible with mechanical equipment. (An example is logical comparison—"branching.") Systems design can take full advantage of these new abilities. Some systems work being done for nonelectronic equipment may be adapt-

able for electronic systems, but because of the added capabilities it may be more economical to go directly into electronics.

Any use of equipment requires some systems analysis. Redesign of forms and reports, and testing of changes before their adoption are needed to assure continuity of operations. Management that has made a substantial investment in a mechanical system may be reluctant to consider electronics, despite demonstrable advantages, until competitors have moved far ahead.

Specific Considerations for Integrated Data Handling. In designing an integrated data-processing system it is necessary to start with specific recognition of the various needs for the data: the requirements of such groups as the outside auditors of the company, the stockholders, the government (for tax and other reports), and trade associations. Occasional needs, as for newspaper publicity or use in advertisements, should also be considered.

Too often the approach taken at present is to create a data-processing system which meets only the inescapable needs, such as for billing of customers, preparation of tax returns, and for publishing annual reports. To this may be added some kind of cost system, in many cases operated by an entirely separate division of the controller's department. Then, in progressive firms, a further modification may be introduced by the creation of staff analysis groups, empowered to gather and present statistics for special studies. Each operating department creates its own requirements and may build up its own data system.

Even though they have a "whole system concept" as the basis for their work, systems groups have found it advisable to begin their integrated studies by working on fairly independent segments of the over-all system. They start by attempting to solve the needs of all the interested end-users of the data in a particular area of operations.

In so doing, there is always a danger that practice and theory will differ. If the installation is to keep from too narrow an approach, some method must be found to remind the individual analysts of the over-all objectives of their work.

In general, the following considerations are typical of those to be remembered:

1. Management's need for planning and control information.
 - a. Different types of information for different managerial levels (condensed versus detailed data, charts versus figures, extent of written explanations, etc.).

- b. Different frequency of reporting for different purposes.
 - c. Different forms of analysis for different purposes (exceptions, variances, trends, etc.).
 - d. Availability of stored information, to answer special inquiries for analysis to prepare special reports, etc.
- 2. Routine operating needs.
 - a. Daily and periodic accounting requirements, for billing, inventory, cost accounting, payroll, payables, cash receipts and disbursements, etc.
 - b. Production requirements for scheduling, requisitions, orders, etc.
 - c. Personnel information for manpower assignments, turnover, etc.
 - d. Stockholder information.
 - e. Sales and market information.
 - f. Capital asset control.
- 3. Requirements for internal audit.
- 4. Legal and tax requirements.
- 5. Requirements for external audit.
- 6. Requirements for published reports.
- 7. Data for trade association and government agency requests.

These are only in the nature of topic headings. Under each, a set of fairly detailed requirements should be established.

Measuring the Requirements for an Integrated Data-handling System. It is not easy to set up rules or guides which can be used to choose the best system. The subject has received considerable attention in recent years. Systems and procedures groups are to be found in almost all large organizations. But in spite of the elaborate manuals which they have developed, few are able to define and measure all the requirements for integrated data-handling systems.

An illustration of the difficulty can be seen in the present problems of many companies which manufacture and install electronic systems. Their engineers have learned how to make machines which will operate at startling speeds. But still, they and their customers have had difficulties in making efficient installations. The manufacturer must rely on the customer to detail his needs, but the customer has difficulty in doing this in a useful manner.

There are certain requirements for integrated data-handling systems which apply to most, if not all, data-handling routines. These requirements can be described precisely and measured quantitatively. Some

consulting firms refer to this as "information engineering." Specifications can be established for a communications system just as engineering specifications are determined for a building.

The first step is to define as precisely as possible the various aspects of the availability of information and of the need for information. Next, the volume of data and rate of flow must be measured. Then the communication and processing links can be built.

This means the study will determine the points of use of information, the types of information required at each point, the time when the information is needed, and the forms in which it is desired. These items are then examined to determine overlaps. In this way unnecessary duplication is eliminated and provision of data for several similar needs can be unified.

Company analysts can determine where original information can best be obtained in order to meet the requirements. The type, form, and time of record are important. The degree of accuracy required in the data is of economic significance, as is the ability of one recording point to serve several needs.

With these items defined, the next step is to measure the volume of information which must be handled at both the point of origination and the point of use. The rates of flow at various times is also significant.

Only then can the processing specifications be "engineered." The needs of the integrated system then can be related quantitatively to the abilities of various devices for data recording, processing, storing, and output. While electronic systems offer considerable advantages in many situations, all other possibilities should also be considered. In some cases, for example, direct observation by the user may still be best.

Processing requires consideration not only of arithmetic calculation, but also of "logical" choice, collating, sorting, and of other abilities. In addition, storage volume and speed of access are important.

After the measurable factors have been determined, then other requirements which are more qualitative can be taken into account. Some of the qualitative aspects which should be considered in integrated data-handling systems are:

1. *A record must be made of all accountable transactions and events.*

In some cases the record must be precise (particularly for trans-

actions involving outsiders), and in other cases estimates will do. The degree of necessary precision should be determined.

For some items the source record should be preserved, in other cases it is less necessary; the length of time for each should be established. In some cases the point of origin of the information is vital and should be recorded; in other cases it is not necessary. (For example, as a rule it is considerably more important to know at what place a customer makes a purchase from the company than it is to know at what place she pays her bill.)

2. *There should be a way for authorizations to be recorded.*

In most cases today authorization is indicated by signature of a responsible party, placed on a document. If the proposed electronic system bypasses the manager, or eliminates the paper document, some other means of control—perhaps statistical analysis with rapid feedback—will have to be established.

3. *There should be a means for subsequent checking.*

The validity of the entries, the accuracy of the processing, the propriety of the classifications used in summarizing, and the physical existence of items reported on, such as inventory, all should be subject to audit.

It appears likely that in many cases this check will not be an actual retracing of data flows, as in some present auditing procedures, so much as a testing of equipment and systems design so as to indicate a high probability that it is performing satisfactorily.

These principles can be applied to any proper system. They always have been considered, to some degree, when installing and monitoring a data-processing system. But in the past, each point could be assessed as the system analyst went along, as he worked on a particular routine, since his decisions would have only a minor effect on other routines.

The volume or rate of flow of the data did not have to be measured too precisely, since the systems usually could be expanded by adding more clerks and machines. Now it will be important for all of these factors to be measured in advance so that the systems engineer can determine the extent to which each must be taken into account in designing the system.

Some work has been done in this area by large companies, but the results are not generally available as yet. However, even if they were, it appears unlikely that a company could learn more than certain

general principles and certain patterns for setting procedures. Specific measurements obtained by one company are not likely to be applicable to the system of another.

Summary—Integrated Data-handling Systems. Current application studies for electronic systems have shown that regardless of cost, size, or character, a major requisite is the measurement of the quantitative requirements. Availability of such specifications is rarely found. Therefore studies must be undertaken to gather the data.

The requirements are generally shown in terms of flow charts or process charts, by specific functions. However, some work has been done to apply mathematical techniques. These are used to set forth the requirements in an orderly and logical fashion, so that the data can then be evaluated. Mathematical models already have been built for applications such as production scheduling, inventory, control, and budgeting.

The desirability of mathematical model building for data-handling systems is becoming recognized. The use of such models has shown the following results:

1. The mathematical models have permitted companies to experiment with their systems before altering actual procedures.
2. The models have been helpful in establishing the "engineering" specifications for the electronic system.
3. Analysis of the models has made it possible to eliminate useless, outmoded, or redundant information and reports.

So far, systems analysis has been aimed primarily at improving the basic patterns for the "combining" form of flow-data handling. For the most part this is the basic structure already employed in data-processing systems. Individual items are grouped and regrouped. They go into departmental, product, and other cost totals or revenue classifications. They end up summarized on operating reports and company-wide statements.

An example of a mathematical method for providing a "descriptive model" of the business situation, applicable to a study of recording data and the document flow through a present business data-handling system, is found in Appendix 4.

CHAPTER TEN

Automation and Scientific Computation

Mathematics and electronics will have far-reaching effects on business operations through their impact on information-processing systems, on automation of the office, and on management planning and control. But electronics and mathematics also have important applications in other major areas—automation of production facilities, simulation of problems, and scientific computation for engineering and experimental purposes. This chapter will attempt to describe these subjects sufficiently so as to indicate the significant relationships between them and the topics discussed in earlier chapters.

AUTOMATION

For years production men have been seeking ways to make their operations more mechanical and less dependent upon the human worker. In some cases, such as in soft drink bottling plants, this mechanization has been achieved to a very high degree. But though “cam and gear” mechanization can be included as part of the significance of the term “automation,” it is not all of the picture. In most automation the machinery does not simply go through a repetitive operation. Rather, it is designed to perform any of several operations, dependent upon automatically supplied instructions.

In more complicated situations the machinery can adjust its performance, as it operates, in order to keep the product within specified tolerance limits. The machine achieves this control through a feedback loop, often called a “servomechanism.”

The “servo” measures the operation as it proceeds, and initiates adjustments to keep the process under control. A thermostat for the furnace is an example of a servo.

The next step is to link a number of machines. Each has its own controls, but they are integrated so that the machines will process and pass the product from one to the next, in effect as though they were part of a larger machine. The various parts perform the necessary operations in accordance with a program of instructions. In addition, the operations are modified by controls which "watch" conditions as they develop. In such a system, various products can pass from one end of a line to the other, untouched by human hands.

The final step in automation, not yet achieved, will be to link the production system with an electronic data-processing system and the management planning-and-control system. Then all the necessary production information would be gathered automatically as the line moved, all the information necessary to program, schedule, and control operations would be automatically prepared, and the control data would be returned from the central information system to the line, as required.

Some experts have compared this system with the human framework: the control motors, hydraulic mechanisms, pneumatic valves, etc., are the "muscles," the electronic monitors and networks are the "nerves," and the central computer is the "brain." (The analogy is useful only for emphasizing the integrated nature of the system; as was indicated earlier, human mechanisms are so much more efficient than present mechanical systems that the comparison is somewhat dangerous.)

The goal for management is complete integration of the whole system—management purpose, executive decision, production operation, marketing operation, and control information. To reach this final step it will be necessary to design both the "automation" system and the system of planning and control as one entity. The business organization must be balanced, with the various activities mutually supporting, their purposes consistent with the purpose of the organization as a whole, in the same sense that the members of a healthy human are so coordinated.

Requirements for Automation. It has been found that the requirements for automation have much in common with the requirements for systems of electronic data processing. Innovations have not been easily introduced. Most installations have been of devices for handling specific parts of the whole operation. These installations have reduced manpower needs, increased productivity, and lowered costs. However, as with data processing, the full benefits of automation are expected to

be achieved only when the devices can handle the whole process—can start with the inputs, raw materials, and carry through to the outputs, the packaging and delivery of the product.

As with the development of electronic systems, the government has been a primary source of support for research and for pilot installations of automatic controls. Weapons research, both for control of the weapons themselves in combat and for automation of their production, has been a major project of the Defense Department in recent years. In addition to encouraging manufacturers by bearing the costs of this research and development, the government has sponsored research directly by supporting a number of groups located in universities and other research centers in various parts of the country. Unfortunately much of the work of these groups is still classified as secret. However, some of their findings have been made available to business, and it can be hoped that the flow of information will increase as the reasons for classification dwindle with time.

System Analysis. Automation, like integrated business-data systems, requires that the production plant be studied as a whole. It has been found necessary to consider the product, its design, the components which compose the product, its functional use, and so on. The requirements must be analyzed to determine what can be combined, simplified, or eliminated, using automatic equipment. The whole system must be geared to its purpose, in the same sense that the design of a bridge or the architect's plans for a building are based on the purpose of the structure.

Attempts to introduce automation have uncovered the need for development of a body of knowledge to bridge the gap between automation engineering and managerial planning and control. Otherwise, for example, automation has sometimes solved the production problem so well that it created new financial or sales problems. Poorly planned automation has unbalanced the production line when applied only to a part of the production system. Unless applied to the most serious problems, the more successful it is, the worse bottlenecks it creates. Automation must be programmed so that it is applied at the right places and in the right order of application.

Personnel Change. Automation usually has resulted in substantial reduction in the labor force and in needs for middle management, with all their supporting functions. Many problems of change-over

have had to be met. Besides the rather obvious changes, such activities as communication have had to be reprogrammed. Considerable information which was accumulated, transferred, processed, and analyzed as part of the duties of the displaced personnel now is being handled automatically. Devices are needed to monitor the automatic machines as well as to provide the information which is needed for planning and control. Sometimes new kinds of information have to be provided.

Compatible Design. Centralized automatic controls, while available for single situations, have not been developed for larger, complex installations. Design of automatic, centralized control equipment will require that an over-all framework be established for the factory, much like that for electronic systems in management planning and control. The various functions must be carefully defined as to their requirements, accuracies, and speed of operation. Equipment at each substation must be sufficiently reliable to correspond with the needs of, and be compatible with, the operation immediately before it and after it.

Illustrations of Compatible Design. The Ford engine plant employing some eight thousand people at Dearborn, Michigan, is an example of partial application of automation. It uses automation equipment to do the heavy work of lifting, turning, and moving bulky engine blocks and other parts through machining, assembling, and testing.

Another Ford installation is an example of more complete automation of a process. A system about the size of a football field performs 540 separate operations to turn out engine blocks at the rate of 100 an hour. A few men at control boards monitor the whole system.

In the field of distribution, Lever Brothers have a system which receives cartons of various products, intermingled. It automatically sorts, shunts them onto individual feeder lines, loads them on pallets, and delivers them to docks or to the warehouse floor. Sorting is handled by electric eyes, which read a series of identity stripes on the cartons. The eyes actuate switches according to the dimensions of the stripes.

Two of the leaders in the production of equipment for automation are General Mills and United Shoe Machinery. Both companies have been so successful in developing devices for their own use that as a

result they have found new products. The markets for these products are far different from those in which the companies were originally engaged.

As might be expected, all manufacturers of electronic equipment are strongly interested in automation. Admiral is an example of a company far advanced in this field.

Flexible Production. An important aspect of automation, not always fully recognized, is that the products of such a system need not be uniform. It is possible to govern the controls on machinery by means of systems using magnetic tape or punched cards. By using a computer to prepare these "instructions," it is possible to obtain a different set of specifications for each product that comes off the line, if desired.

Or, as appears more likely, automatic equipment can be set to assemble a variety of parts. Each of the parts can be mass-produced, but the combinations can be varied. Automobile assembly lines already achieve this with various color combinations.

Automation of the office follows similar principles. Certain elements of each transaction record are unique. These can be stored for reference, but they are screened out in the processing. The common elements are grouped in various ways on different reports. This "combining" can be handled automatically in an electronic data-processing system.

Automation—Limitations and Obstacles. Automation is introduced only where it will pay. Most physical operations in business can be performed by a machine. The limitations are largely economic. It is necessary to determine whether it is worthwhile to spend the money to design, build, and operate the necessary equipment, especially in view of the research that must be done to fill some of the present gaps in our knowledge.

Technological Obstacles. The rule in the past has been that the simpler, more repetitive, and more frequent the operation, the more likely that it can be successfully mechanized. But with automation a new element is introduced. It is no longer necessary that the process be exactly repetitive. Instead, the requirement is that the purpose of the process be known and measurable and that the operations be controllable. As in programming and scheduling of management decisions, this places considerable emphasis on the control-feedback mechanisms.

The significance of this can be seen in many current installations, particularly in modern petroleum refineries. In typical systems there is a combination of completely automatic minor controls, combined with over-all human control by operators who watch instrument panels.

In general, automatic control can be established wherever the relationship between the incoming information and the required correction can be predicted. Such measurements as those involving pressures, temperatures, rates of flow, and levels are frequently of this type.

Where the process is more complex, measurement of all the variables is seldom accurate enough to permit completely automatic control of everything. There are points at which it is more economical to rely on the human operator for control. An intelligent human is a very effective "device" for this sort of operation—he has rapid and reliable input (reading dials, etc.), rapid access to a large storage (his memory), and efficient output (pressing the right buttons, etc.).

Most important, human judgment can compensate for feedback inadequacies. The essence of human control is the fact that an intelligent man has the ability to control without complete information. Of course, the better the information presented to the human, the more effectively he can operate. Control panels in refineries, etc., are built to give a remarkably good picture of the process flow, but even they are not sufficient to make the process control foolproof, without human monitoring.

Personnel Limitations. Automation requires personnel trained in systems engineering. They must be able to integrate the various functions and subfunctions of a business. Few such engineers are available today. Most engineering schools have encouraged specialization, such as mechanical engineering, electrical engineering, civil engineering, and so on.

In addition, the mathematical training usually given engineers, while greater than that in most other fields, is frequently not suitable or sufficient for systems engineering. As a result, most engineers are capable of automatizing only separate elements of a process, not the whole.

Few good systems engineers are at present available to industry, compared with the demand. The advance in automatic military systems has led the government to train some systems engineers, but the number of engineers is not large and their training is not always suitable for commercial work.

High Cost. Automation usually requires a substantial investment. New machines are required, as well as better instrumentation and more accurate and flexible controls. Salaries for competent personnel are high, and their work takes time. Systems engineers need the help of mathematicians and of production engineers for defining the control problems, for measuring the relevant variables, and for designing the integrated system.

Project Tinkertoy, which was sponsored by the Navy to produce electronic circuits automatically, required almost \$5,000,000 to develop a pilot plant.

Eventually, the cost of automation should be substantially reduced through improvements in production machines, in the logical design of computers, and by other means. Meanwhile, partial applications will continue to be fairly expensive, though in particular cases they often can rapidly repay the necessary investment.

Summary. Fully automatic factories will be built some day, but for most industries that day is not tomorrow. Devices are now available for partial applications, particularly for material handling and for control of certain types of machine tools. It is this type of automation which is being attempted first.

The requirements of the Department of Defense will continue to encourage development of automatic weapons, and automatic means for their production. Use of the knowledge gained in this research may be expected of many businesses which seek government orders.

Successful automation by competitors is a threat that businessmen cannot afford to ignore, even though they might prefer to wait until better systems become available. Despite many obstacles, accelerated use of automation appears inevitable. Because of these pressures, the problems of the executive will be increased over those that might be expected if development of automation could be studied more leisurely.

SCIENTIFIC COMPUTATION, MATHEMATICAL COMPUTERS

Still another major development which must be considered is the availability of computers designed to do scientific computation. These were the first models of electronic computers. Complicated engineering problems almost always require a certain amount of mathematical computation, and advanced scientific work relies heavily on mathe-

matics. As a result of these needs, and spurred by the large sums of money available for defense effort, the development of electronic equipment for high-speed computation has proceeded at a remarkable rate. Most of the equipment now offered for data processing has descended directly from these scientific computers. In some cases all that has been done to change over the design has been to improve the input and output capacities, and in some cases the storage.

Electronic computers designed primarily for computation already are used by business to a surprising extent. Volumewise, it is probable that more computation has been carried on by them in the few years since 1949 than by all other means in all prior human history.

The cost of electronic data-processing systems is so substantial that it will be easier for executives to justify acquisition if other uses, such as for engineering or actuarial computations, can be shown in addition to the routine data processing. On the other hand, it has been found in many cases that if needs for large amounts of computation occur irregularly, they can be served better by making use of the computing services established in various parts of the country. Most scientific computers are available on a rental basis, by the hour. Also, manufacturers of business computers are already offering this type of service.

For example, a number of Detroit manufacturers cooperated to purchase a Burroughs computer, now installed at Wayne University. Among others, General Motors and Ford contributed substantial sums to this installation. The money is being used for studies of production scheduling, engineering computations, and for market analysis.

These centers also will handle what is coming to be known as "data reduction," the routine processing of large amounts of data, such as observations made during a scientific experiment, or regular production reports. Data reduction may make use of complicated mathematical formulas, but it is not experimental, in the sense that the formulas used are known and tested. The operation may be compared with assembly-line production of physical objects. For example, General Electric has found that there is so much work of this sort for its IBM 701 at Cincinnati that it has arranged to send extra work (beyond a 24-hour-a-day load) by wire to other machines, including the IBM service center in New York. The reader will recall that the 701 is a machine which can make several thousand computations a second.

Data reduction is coming to be a sizable business by itself. A num-

ber of firms have been set up to handle such work on a contract basis, and university computers receive considerable support from this source. The next section will describe briefly some of these activities.

Some Problems Solved by Scientific Computers. It is difficult to generalize as to types of problems which have been solved by these mathematical computers. Almost every scientific field has been affected. However, description of a few problems, together with mention of others, may show how these machines have been used.

Many types of problems involve the use of prepared tables. The machine can store these tables in its tape or high-speed memory, and refer to them at appropriate points in the computation. The tables are first prepared by the machine itself, of course, following predetermined formulas. In many cases it is not necessary to prepare a whole table, since the machine can also recompute from the formula as it goes along, unless the formula is so complicated that it fills the high-speed storage of the machine.

Many problems are of a type in which the result of one computation is used in the next computation. The machine can carry out millions of computations, in which this "retracing" occurs in the sense that the machine does the same sort of calculation over and over, using the result of the last computation as a factor in the next. Thus the same set of instructions will serve for a major part of the "program."

For example, to calculate the path of a projectile, the machine can weigh such factors (mathematically speaking) as the weight of the object, the speed of acceleration, the force of gravity, the air resistance, the curvature of the earth, and so on. It calculates where the projectile will be a split second after firing. At this moment the projectile will have a certain position and speed, which the machine uses in calculation of the position and speed a split second later, and so on. The result can appear either as a table of figures or as a plotted series of positions on graph paper.

Carrying the same example a step further, the computer can operate in "real time," while the projectile is still in the air. Through use of telemetering devices, information concerning the flight is sent back to the computer. The computer produces answers in a form which can be sent back to the projectile in order to control its course.

In other cases, the computer may be part of the projectile. The computer may evaluate such matters as the relative positions of the projectile and of the target which the projectile is approaching. The

computer system converts radar readings to mathematical form and correlates them with the position of the projectile and the controls on the projectile. This type of electronic control loop is the basis for much of our country's guided-missile effort. In a real sense the electronic computer is part of our first line of defense.

The use of a computer for such purposes may at first glance appear to be a far cry from any commercial application. However, knowledge of these developments has led to such statements as that by an executive of General Motors, to the effect that they could now build a car which would steer itself down the highway. The executive quickly pointed out that it would be uneconomical though technically possible to do so.

Whereas it may well be questioned whether it will ever be desirable to produce a self-steering car, the businessman must be alert to the possibility that some such application of computers may become of great importance to his product. An example of a system which comes close to being of this order is the elevator dispatch control now being installed in large office buildings. This electronic system gathers information as to the position of the cars and as to the buttons pressed to demand service; it then computes an optimum car allocation and dispatches the cars automatically.

Differential Equations. Numerous problems which confront the engineer involve measurements which give rise to relationships that are expressed in differential equations. For example, the distribution of magnetic-flux density in an electromagnetic device, or the distribution of stress in an elastic body, or velocity and pressure in a fluid are measured with "partial differential equations."

A major difficulty with these situations is that to solve these equations usually calls for a carrying out of a great number of computational steps. To handle these problems it has been found economical to design and build special types of computers which analyze differential equations. Both analog and digital systems are used for this purpose.

Success with these special-purpose machines has led researchers to hope that similar special computers, designed to incorporate improved mathematical methods, may some day enable them to handle a variety of business problems which are now beyond reach because of the complexity of the situations involved.

For example, the possible routes in a production shop, with attendant costs and times of completion, give rise to equations of fantastic com-

plexity, using present knowledge. It is believed that some new variety of combinatorial mathematics, together with new computer designs, will be required if such problems are to be handled electronically.

Another problem is the representation of minimum cost and maximum revenue curves. Quadratic equations, or even more complicated models, are required to produce curves that "peak" and "valley" in this fashion. Again a special type of computational design may someday give a technological breakthrough in this area.

EXAMPLES OF COMPUTATIONAL APPLICATIONS

To round out the picture of the scientific computer and of large-scale computational problems, a few applications will be described, followed by mention of other problems on which these machines have worked.

The RAYDAC and Teleplotter at Point Mugu. The Raytheon Digital Automatic Computer (RAYDAC) was developed for the U.S. Navy Bureau of Aeronautics to analyze guided-missile flight problems.

When a guided missile is launched, ground radar stations record its speed, altitude, and direction. Inside the missile miniature transmitters send out information on the speed, how fast it is using up its fuel, the temperature of the missile's engine, its angle of ascent, and so on. All this is coded and given to the computer, where the problems of flight are analyzed to determine such matters as stability of the design, tendency to yaw, etc.

The data are punched on cards, which are given to a "teleplotter." This device is a machine about the size of an ordinary office desk. It can translate numerical data into chart form, through use of a swinging head that counts the grid lines on a chart photoelectrically, and automatically plots positions as they are fed to the machine.

Incidentally, given data such as are customarily developed for a break-even chart, this device could draw the chart in a few minutes. However, the machine is able to work with much more complicated data than are usually developed for this purpose by business analysts.

The value of this equipment lies primarily in the speed with which it makes the results of an experiment available to the researchers. In the past it was necessary to gather data at a test station, then carry them back to offices for days or weeks of computation to discover what happened. Now it is possible to analyze each flight as it occurs. Analo-

gous advantages for various types of business experimentation are obvious.

UNIVAC and the Election. One of the most publicized statistical uses of electronic computers occurred on election days in November, 1952, and November, 1954. In 1952, for example, the UNIVAC was used to make a forecast of the presidential result at a time when less than 6 per cent of the vote was in, with no returns at all from 21 states.

The situation is worth some discussion, since it illustrates the careful planning which must precede the handling of data on the computer. About a month of working time was spent to formulate a theory of election mathematics, which detailed equations showing the relationships between early returns and the final results in previous elections.

The preparation for the application lagged, and as the deadline approached more and more workers were added to the project. The final "program" was completed on election day. There was no time to test it out.

When first returns of about 3,400,000 votes had been received, they were fitted into the equations, given to the machine, and the calculation started. The actual machine running time was about 6 minutes, after which a detailed forecast of the probable results in each of the 48 states was printed out. The forecast gave 5 states to Stevenson and 43 to Eisenhower. Since the program had not been tested, the group decided that this might be erroneous and withheld the first prediction.

In the 1954 election the most interesting event was the mistaken prediction which resulted from an inversion of the data. At one point the machine was given Democratic returns as Republican, and vice versa. The machine was not programmed to catch such errors and so gave an erroneous prediction.

In neither case were any of the errors the fault of the machine. This case forms a perfect illustration of two possible sources of difficulty in using electronic equipment. The first election forecast was not trusted because it had not been possible to develop a formula which showed the exact relationship between early returns and final results. The approximation, however, was surprisingly good. The second was a human operating error under hectic conditions.

The election case is of interest for another reason, of a more theoretical nature. For many situations, especially in the physical sciences, a researcher attempts to find a formula, or a set of rules for a procedure,

which leads to a specific, precise answer to the problem. In business, however, such precision is seldom necessary. The situation often is so complicated that the analyst may not be justified in trying to find a formula that will precisely relate all the variables. Instead, a numerical approximation may be sufficient. If this shows only some statistical probability, it may provide a useful solution to the business problem.

The election forecast was of this type. An examination of past relationships showed that when one group voted in a certain way, then another group had voted in a certain way. This was expressed as a numerical relationship. There was no need for the forecasters to worry about why this had been so, unless there was some reason to believe that events had changed in such a way that the old relationship might no longer hold. (An example of this might be the case of a native son candidate who might be expected to carry his home state with a higher presidential vote than his party would otherwise poll.)

Given a set of these numerical relationships, the machine showed what the result probably would be. Such an indication often is all that is required as a basis for an operating decision.

UNIVAC at the Bureau of Census. The first UNIVAC was installed at the Bureau of Census in March, 1951. By employing the first large-scale computer designed to perform accounting and statistical operations, the Bureau of Census has rightfully claimed to be following in the footsteps of the Bureau in the last century, since the first large-scale application of punched cards was made for the calculation of the 1890 census.

The UNIVAC was assigned part of the preparation of the "Second Series" Population Tables, which contain 30 tables covering age, sex, race, country of birth, education, occupation, employment, and income. The tables show statistics for thousands of categories—for each county, city, rural farm, and rural nonfarm area within a county.

The raw data were prepared in the form of a punched card for each individual in the United States. The data from the cards were then transcribed onto magnetic tapes. The tapes were used to tabulate each individual's characteristics, in groups of about 7,000. Then the groups were used to produce data for the categories, from which the tables were prepared. The tables were printed out on the machine's printer. The operation was primarily one of addition, to a number of predetermined totals.

In reporting the results of the UNIVAC operation the representatives

of the Bureau have estimated that the cost of this operation was about half that of their regular method. They also reported that the machine had operated so accurately that they had not found any errors which could be traced to machine malfunction.

Air Force Programming. At an unclassified conference held in Washington in 1953, a report was made of an application under way to use an electronic computer for an Air Force problem.

The model problem was designed to provide a document listing of the amounts of selected material needed to support a war plan. Aviation fuel and lubricants, ammunition, guided missiles, aircraft guns, assist take-off units, auxiliary fuel tanks, pylons, chaff, photographic film, boats, drop kits, and drop sondes are examples of the classes of items for which detailed item requirements were computed

Monthly schedules of requirements were obtained for each of the material items after an assumed D-day. Allowance was made for the expenditure of material by combat aircraft and by aircraft engaged in other missions, such as training. Important kinds of losses, stock levels at installations and depots, and transit times entered into the determination of requirements.

It was determined that when data are prepared for the computer, it is most efficient to arrange them in a manner which simplifies the hand-work and writing of numbers because these operations, when performed by people, have a greater error rate and are much slower than those performed by machines.

The machine was programmed to make computations which would yield levels of material requirements by months. These were printed out in tables with descriptive headings.

In making the computations the machine used a reel of tape which contained the data from the war plan. These data dealt with flying of diverse kinds. Schedules of deployed aircraft by type, model, and series were shown for each month, for the continental United States and for overseas. The number of various kinds of aircraft were listed for the various kinds of schooling and practice, such as crew training, joint training with the Army, tactical support, individual training, administrative flying, testing, and special mission. Information on crews and on individuals completing training each month were also listed. In addition, there were schedules of aircraft accepted by the Air Force from manufacturers for delivery, and allocations to fighter-bomber interceptor units and other kinds of units.

On another reel were the data which showed monthly hours of use for each kind of aircraft, gallons of fuel consumed (per flying hour), material items expended per sortie, rounds of fire in life of weapons, material loss factors, and pipeline times for transit and for installation, etc.

Three blank tapes were mounted in the computer to handle the requirements of computation and results. The results were then rearranged, edited, and merged with descriptive alphabetic information, before printing.

The instruction tape in this problem contained a central computing routine 650 words long, with 12 characters to a word. On a punched-card run of a similar problem, such a computation routine previously took some 16 plugboards containing 3,818 wires. Preparing the computer instructions took about as long as wiring the plugboards. However, once prepared, the computer instructions could be stored in a sewing thimble, while the plugboards took several cabinets. Moreover, the machine automatically selected the next routine from the tape, while humans had to be entrusted to select the right plugboard.

The program data used consisted of some 15,400 activity levels. The computed results contained 57,500 activity levels. The planning factors used numbered about 144,000.

In addition to this problem dealing with combat consumables, the Air Force has experimented with test computations of military personnel requirements by Air Force specialty code, aircraft-engine procurement, overhaul and shipping requirements.

An interesting result of the experience was the discovery that the greatest difficulties were encountered at the start and at the end of the experiment. The experimenters were faced by the fact that many of the decisions they were measuring had always been made on a judgment basis, were not governed by the same factors as previously used, and thus were difficult to estimate.

The conclusions were that this approach promoted consistency in the scheduling process, allowed a self-checking computer to do the tiresome and time-consuming part of the work, permitted a systematic presentation for review, provided for rapid recomputation when program assumptions led to unacceptable results, and released manpower to be used on planning factors and on other areas which require judgment.

Bureau of Aeronautics. The Bureau of Aeronautics must determine when to order government-furnished equipment for airplane-production lines. Some items are needed as much as 18 months before the airplane is scheduled to be completed, while some items need not be furnished until 3 months after completion, when the plane is delivered to the point of use.

One piece of equipment, such as an engine, may be delivered to as many as 325 possible destinations—one of the services, a foreign country under Mutual Security, the fleet, etc. Quantities required may differ for each. A single plane may be furnished with from 25 to 230 items of aeronautical equipment.

Changes average about 50 a week in the equipment alone. Revisions of schedules and quantities occur frequently.

About 70,000 punched cards were maintained by a staff of 22, working full-time with considerable overtime. When an important change in the schedule occurs, as many as 50,000 of the cards may have to be changed.

The problem was placed on a National Cash Register's CRC 107. Source data were placed on two master tapes. The first, called the airframe tape, consisted of 10,000 words of computer information. Each airframe was identified by a particular code stored in the address word, followed by space for 50 words of information for that airframe. These include the manufacturer and plant location, fiscal year, end user, source type, contract number, priority, unit cost, total cost, total quantity of airframe for fiscal year, total to date, balance due, month in which the schedule first starts and when it ends, and a monthly schedule of airframes for the next 3 years.

The other master tape was called the equipment tape. It consisted of some 60,000 words of information. Each piece of equipment had a code in the address word, followed by the codes of the airframes that used this equipment. The fiscal year of use, end user, source type, quantity of equipment per airframe, installation lead time, and application were stored as information.

The procedure started with a particular piece of equipment. The computer was programmed to search the airframe tape for the first airframe noted as using this equipment. When a match was made between the corresponding airframes on the two tapes, a further search was made down the airframe tape, to match the corresponding end

users and fiscal years. This search was required since the same airframe was reproduced several times on the airframe tape, for varying fiscal years and end users. Once the match desired had been achieved at all points, the computation consisted of determining the monthly quantities of required items in the form of a schedule—which thus became the “program” for operations.

Sales Analysis. A study conducted by the Retail Department, Bureau of Advertising, American Newspaper Publishers Association, made predictions on how and when people would buy 28 basic lines of merchandise over a period of a year. Trends as reported for the years 1941 to 1952 by the Federal Reserve Board sales in department stores, nationally and by districts, Department of Commerce seasonal sales, trade association reports, and analyses of advertising by 91 commodities were correlated by the least-squares method. The UNIVAC was used to prepare the tables, which showed that 1954 patterns could be expected to parallel closely the 1952 experience.

Based on this confirmation, the Bureau issued a 58-page “Annual Time Table of Retail Opportunities” to its 1,012 member newspapers. The study had showed that during the years 1941 to 1952 the seasonal pattern of total department-store sales fluctuated less than 2 per cent in any one month, despite the war, scare buying, and so on.

A series of 336 trend lines were calculated in $3\frac{1}{2}$ minutes of machine time. Comparable hand computation would require over 200 man-hours. Programming the machine required considerable time, which cut down the margin of saving, of course, but if the formulas hold for another year, the program can be reused.

Summary. There are well over 100 large-scale electronic computers, designed and installed by universities and research groups in this country and abroad. Almost all of these are engaged in what can be called “scientific computation.” In addition, hundreds of large and medium-size commercially produced computers are working for industry on data reduction.

The use of these machines has opened new horizons for engineers and scientists. Many problems which formerly were avoided because the computation required was known to be too large to be handled economically now are treated on a routine basis.

General-purpose computers designed for business data processing usually will handle scientific computation. Groups studying business computer installations can justify part of the cost by demonstrating

that the systems will aid not only the engineering department, but also make economically feasible the development and use of mathematical models for production, marketing, and financial analysis.

SIMULATION

Simulation is a term which is analogous to model building. The term signifies the construction of devices which solve problems by imitating the physical characteristics of a situation, or the translation of these characteristics into measurements which can be manipulated in a mathematical sense.

The devices are often in the form of an analog system. Sometimes, if versatile enough, they are in the form of an analog computer. An analog computer can solve many of the same types of problems as do digital computers. The difference lies in the fact that the measurements are not precisely quantified into digital form, except perhaps at the input and output of the computer.

Digital computers also can be used for simulation.

A simple example of an analog system is the slide rule, in which distances simulate the logarithms of numbers. Other mathematical relationships can be simulated in physical terms through the use of various types of equipment. A device much used in defense work employs gears and wheels, which rotate against each other in certain ratios, giving quick and reliable answers for such problems as fire control for weapons.

As a rule analog systems are relatively easy to construct, cheap, and easy to link to other devices. They are now used in many types of situations, varying from controls that are hardly more than thermostats all the way up to quite complicated equipment, such as the well-known Link trainers that simulate air flight for ground instruction of aircraft pilots, or devices that offer military commanders hundreds of choices in "war-game" simulators.

As the devices become more "general-purpose" they approach the status of a large-scale computer. Computers can be made to handle complicated mathematical transformations to a high degree of precision. They have been used to solve complicated aerodynamic problems.

It is also possible to make relatively inexpensive analog devices that are accurate to sufficient decimal places so that they can operate on

numbers and give digital answers. The extent to which this ability will be developed in the future is uncertain, especially for business purposes which require digital information. However, it is a field which the executive should watch for development of devices which can aid his control operations considerably.

Claude Shannon, who was one of the first to set down the logical analysis which underlies much of modern digital computer design, also has given an indication of the direction that new improvements may take. He and other researchers are studying electronic systems that can handle nonnumeric operations. These systems perform logical analysis, translate languages, design circuits, play games, coordinate sensory impressions, and, generally, assume complicated functions associated with the human brain.

Nonnumeric computation will be handled by a new type of electronic computer, one capable of carrying out a sequence of orders relating not to operations on numbers, but to physical motions, operations with words, equations, incoming sensory data, or almost any physical or conceptual entities.

Other analog devices make use of such things as mechanical shaft positions, signal frequencies, and light intensities. The accuracy and reliability of analog systems, while adequate for many purposes, are limited by the degree to which it is practical to design and construct precision instruments. Digital computers, of course, are completely accurate, once the input is established, as long as the system is functioning properly.

Analog devices have several advantages. Analog control is usually, in essence, a working model of the control function being performed, so the design of the system may require only a straightforward connection of components. Another advantage is the continuous nature of an analog device, which often enables it to function rapidly in a closed-loop feedback system.

In a digital system, the computer must sample the data, convert it to digital form, transfer it to some storage, call on the stored program, compute, transfer data back to the control mechanism, reconvert from digital, and finally control. As against this, an analog system may require only one electronic conversion, just as the familiar analog control of rotating weights on a steam engine requires only a simple lever and gear connection.

A new concept, which may amount to a technological breakthrough,

is to use discrete physical events to record a "pulse train" which is never converted to digital form (i.e., numerical), but instead is handled in semidigital, semianalog fashion by an electronic conversion device. These techniques will be particularly applicable to automatic control problems. The use of these techniques has already reduced the number of components, the size, weight, and the cost of certain electronic equipment to about a tenth of former requirements. Further reductions are considered feasible.

It is possible, for example, that some sort of analog devices may be developed which will simulate business problems in the same way that a utility power system is now simulated and controlled through use of model grids.

The Swiss have developed a very complicated mathematical model of their government hydroelectric system, and plan to control the system by using the model on a computer. The economic system of the United States has been represented in model assemblies of electronic circuits, a number of which have been built at various universities as teaching devices.

An operating example of an analog system is an incremental cost computer used by a Southern utility. Current fuel costs at each producing station are recorded and transmitted to the computer. Transmission losses and generating costs are statistically determined. These generation values are transmitted directly from the stations. The computer calculates the cost of delivered power, and the result is used to control the system by adjusting the load at each station.

Conversion Devices. In addition to analog devices, there is growing interest in the new field of instrumentation devoted to counting or conversion of such conditions as speeds of rotation. Devices convert physical conditions into measurements which can be used as input to either digital or analog computers.

The developments are too technical and varied to be discussed here in detail, but they form an important part of the electronic picture. Through their aid it is becoming possible to measure accurately many types of processes as they operate, rather than having to wait to count the finished products as they emerge. Obviously this increases the possibility of rapid feedback and control.

A very simple example would be the possibility of measuring traffic flow in the aisles of a department store, as an indication of sales activity. Many sales managers get a feel for the day's sales merely by

observing the condition of traffic in the aisles. Rather simple electronic devices can meter this flow and show it on dials or graphs in the upstairs executive offices, if there really is value in such information. A more elaborate system could keep running totals of amounts rung up on cash registers.

Devices are now being installed in steel mills, and on large-scale assembly lines, to monitor production operations. They can give quick, reliable information concerning process flows.

Other Types of Problems Which Have Been Handled by Computers. Some idea of the immense variety of problems which have been handled by electronic systems may be obtained from the following partial listing of such activities. They have been used to:

1. Compute the flight path of a projectile.
2. Investigate atmospheric turbulence.
3. Determine spheroidal wave functions.
4. Calculate the shape of nuclear-magnetic resonance absorption lines.
5. Study shock waves, a two-dimensional grid of concentrated masses subjected to impulsive loads.
6. Determine the vibrational frequency spectrum of copper crystal.
7. Do pipe-stress analysis.
8. Do rotating-disk stress analysis.
9. Analyze turbojet performance.
10. Analyze wing flutter.
11. Do meteorological computations.
12. Study traffic flow on freeways.
13. Make geological analysis of oil structure.
14. Do work measurement.
15. Prepare tables of the incomplete beta function.
16. Study stability parameters of aircraft.

Computers are at work in every major country in the world. Certain developments have already come from abroad. Barring increased barriers to transfer of information, this international assistance from friendly nations should continue.

On the other hand, the Russians are evidently well along in electronic systems design. Some of their scientists have been given high recognition for their computer work. Estimates have been made that show electronic development is a major item in the Russian budget.

Their magazines discuss automation as though it were to be taken for granted.

The free world has no monopoly on this knowledge.

Conclusions—Automation and Scientific Computation. The future use of electronics and mathematics in business is by no means limited to data processing and decision making. In addition to the handling of information, electronics will play a large part in the automatic handling and processing of materials. As engineering and scientific designs become more complicated, more and more use of mathematics can be expected together with need for large computation capacity.

The business executive will find that personnel requirements and other such problems tend to be similar in the data-processing, automation, and scientific-computation fields. Moreover, integration of the system is necessary if optimum benefits are to be achieved.

CHAPTER ELEVEN

Role of the Executive in Selection of an Electronic System

The diversity of electronic equipment available and the variety of ways in which the equipment can be utilized offer both an opportunity and a problem. The opportunity lies in the ability to achieve more economic procedures and more effective management planning and control. The problem, of course, is to select the electronic system which will best accomplish this objective.

There is no pattern of experience for the selection of an electronic system. A review of current installations discloses that the following were among the primary reasons for the choice of a specific electronic computer:

1. *Availability of equipment.* Equipment has been in short supply. Some of the earlier installations have been premised upon early delivery.
2. *Satisfactory experience with a particular manufacturer.* Customer relationships extending over a period of years have been continued. Most office-equipment manufacturers are adapting their electromechanical systems to the newer electronic systems.
3. *Special assistance in installation.* The companies that installed the earlier models of various computers received the assistance of the manufacturer's technical staff for lengthy periods at no extra cost. However, this extensive assistance is generally less available now that computers are more widely accepted.
4. *Comparison of alternative proposals, with selection of the "best."* Some companies have asked manufacturers to study and review their needs, and to make recommendations. Other companies have made studies of their requirements themselves and have

requested manufacturers to submit proposals. A number of the companies that have attempted this approach have found that manufacturers could not understand the specific needs sufficiently to recommend the best system. In some cases the different manufacturers' proposals were difficult to compare. Generally speaking, manufacturers do not like this method, nor do most experts feel it is advisable except in special situations.

5. *Availability of maintenance, service, and stand-by facilities.* Dependability of operation has been an important consideration. In one case a company was influenced by the fact that the manufacturer's service center was directly across the street.
6. *Special design characteristics of available computers.* Some companies desire particular devices for checking accuracy of data as they are processed. Other companies have required specific input and output equipment which was available from only one supplier.
7. *Improvement of suitability of the electronic system.* A few companies and industry groups have engaged manufacturers to build equipment specially designed for their needs. In most instances the customers believe that the resulting design will be more useful to their industry than are the available general- and special-purpose systems.
8. *Uncertainty as to performance on company operations.* In order to test the suitability of various systems, some companies have deliberately installed several different machines, both as to size and make. Others have appraised equipment by coding their routines and test-running them on manufacturers' machines.
9. *Desire to gain experience.* Many companies have started with medium-size machines in order to gain experience before attempting large-scale installations. Others have begun with large machines. In several such instances the companies already plan to replace the machines with newer models.
10. *Technical characteristics.* Several companies have assessed the speeds, storage capacities, and other characteristics of various components of each computer available. They have selected the one which appeared to offer the most for least cost, without worrying too much about the specific applications.
11. *Recommendation of consultants.* Many companies have hired independent consultants to make an appraisal of their needs

and to suggest the best system. In some situations the executives have relied almost entirely upon such advice.

12. *Adaptation of available equipment.* Companies have adapted available scientific computers and systems to some of their business requirements. For example, one financial company installed a medium-size general-purpose scientific computer. It uses the machine to make analyses and prepare top-level reports from data already processed by other equipment.
13. *Other.* In some instances selection has been predetermined by top executives. Other companies have agreed to partially finance the development of new equipment. This is particularly true of input and output devices. The hope has been to obtain more suitable and compatible electronic systems.

A variety of other factors also have had some influence.

On the other hand, companies have advanced a number of reasons for delaying selection, after careful study of available equipment. Among the reasons they have given are the following:

1. *Technological vs. economic obsolescence.* Firms with advanced electromechanical systems have not always been convinced that electronic computers, though technologically superior, were sufficiently more economical to justify a change-over. Presently available electronic systems were not able to show decisive cost advantages. Some company studies have indicated, however, that electronic systems under development would show more of an economic advantage.

A number of these companies also say that if they were starting a new installation they would use present computers.

2. *Need for detailed system study.* Many companies believe that a comprehensive systems study should be made before a computer is ordered. Until such studies are made, no orders are placed. A few such firms have placed letters of intent to purchase computers in order to get on waiting lists. Some of these have altered their original orders in view of developments.
3. *Executive reluctance.* Some executives do not feel their companies can afford to lead in pioneering work. There are many conflicting reports about first installations. Until there is more evidence of substantial benefits the risk may be too great. The

executives do not want to tinker with organizations which are not giving trouble.

4. *Desire to profit from the experience of others.* A number of companies do not want to commit themselves until they can incorporate the lessons learned from the mistakes of early efforts.
5. *Concern over legal and auditing requirements.* Uncertainty as to the position of certified public accountants and the courts, with regard to electronic and magnetic records, has caused some hesitation.
6. *Executive belief that electronics are not feasible.* Because of the expense of installations, and limitations of input, output, or storage, some executives are convinced that electronic systems are not suitable for their type of business.

This diversity of experience indicates that no pattern for selection of electronic systems has yet evolved. Companies have found it difficult to reach a decision as to their own program. There is no simple, rule-of-thumb answer to the problem of selecting an electronic system.

Many complex decisions must be made. Some are technical. Some are administrative. Personnel experienced in all aspects of this situation are rare. There are experts in various special areas, but there is a problem of communication.

Lack of understanding of each other's problems is not a new experience for executives and the experts. Problems arise for reasons of semantics, differences in the frame of reference with which each approaches his problems, the variety of backgrounds and training, unwillingness to give each other adequate freedom of action, and a tendency to expect tangible results too soon.

Unfortunately, this gap will not necessarily become narrower with time. It may tend to expand unless positive action is taken to prevent the widening. Development of an integrated business system requires an appreciation and understanding of the scientific approach, which in turn usually requires some acquaintance with mathematics. To communicate, therefore, the executive needs better training in the fundamentals of science and in the tools which it uses.

Scientists and engineers, on the other hand, have to know enough about management problems and procedures so that they can explain their concepts in terms that the executives can understand. Among

the executive problems that the scientists and engineers must consider is the fact that executives usually must be able to justify allocation of resources by the expectation of fairly current returns. Programs for computers, therefore, have had to take into account ways to achieve short-run as well as long-run pay-offs.

In an effort to convince management that such pay-offs were available, overselling has sometimes occurred. Lingering suspicions which resulted are still hampering some attempts to install electronic systems.

In dealing with this situation, the executive has two major objectives:

1. *To determine whether his company can make effective use of an electronic system.*
2. *To make sure that his company selects the system best suited to its requirements.*

To determine whether his company can make effective use of electronics, the executive's role is primarily one of selection of competent personnel, providing the environment so they can make the necessary factual studies, and selection of general areas for their evaluation. To make sure the selected electronic system fits the company's management and operating requirements, the executive's role is to ask discerning questions which will indicate to him that all the relevant factors have been considered.

Determination Whether the Company Can Use Electronics. The specifications of the various available electronic systems are usually stated in technical terms. The size of the internal memory of a computer may be expressed as a number of "words," with so many characters or "bits" per word. External storage is usually measured by the characteristics of tapes, in reels of so many feet, with recording densities per inch and reading speeds in characters per second. Output capacity of printers is in lines per minute, with a certain number of characters per line. The flexibility is largely determined by the number and variety of instructions which the programmer can use.

Translation of these specifications to business capabilities is seldom a simple matter. Business needs are expressed in terms of types of reports, numbers of documents, accessibility of information in various combinations, etc.

Most companies which are seriously considering, or have installed, an electronic system have created an analysis group within the com-

pany to handle the technical problems. Decision to establish such a group, however, raises a number of questions:

1. What areas should the group investigate?
2. What type of personnel is desirable?
3. Who should be chosen to head the group?
4. What size should the group be?
5. How can the company personnel be encouraged to assist the group?

Application Areas. Experience has shown that electronic systems usually require several applications in order to be economical. These applications have been found in various areas: accounting, inventory, production scheduling, and analysis of management problems, etc. Frequently the best application on which to start was not originally obvious.

Therefore, all areas of the company should be examined, at least to some extent.

Companies may find that one type of electronic system cannot meet all their needs efficiently. They may need a combination of several types, or several independent systems. For example, production scheduling and inventory control may require an electronic system which has a large random-access memory, but which computes rather slowly—a file computer. On the other hand, payroll may require more speed but less storage, if the data can be sorted before processing.

Team of Experts. To study the feasibility of using a computer in all possible areas usually requires a team of experts. These may include men who understand management planning and control, accounting, application of the tools of management science, production control, sales, personnel, purchasing, electronics, and mathematics.

Yet at the same time it is advisable to keep the team as small as possible. The members of the group must be able to communicate with one another. For this reason also it may be desirable to have the team work on a limited area at first, in order to develop group understanding of each member's language and procedures.

To keep the group small it is often possible to select men with experience in several fields, who can be encouraged to learn still others. In addition, the team can be supplemented by using the representatives of manufacturers. These outsiders can supply information concerning

the abilities of their systems. They can teach company personnel to program and code for the computers. They can also assist the team in understanding how to handle problems by showing them other installations.

The company can also use consultants. These groups may have wider experience than the company men. Consultants may act as impartial judges of manufacturers' products. Often they can supply men for temporary assignments when experts are required for special problems. Some CPA firms, management consulting firms, research institutes, and university faculty members have been active in this field, but the supply of competent men is limited.

Head of Team. Proper selection of the head of the analysis group is important. In most cases it is desirable to choose someone who has a basic understanding of the company objectives and the operating problems it faces. However, he must also have other abilities. Unless he has these other qualifications it may be better to go outside the company.

He must have a feeling for research. He must be someone who can build the computer system and continue the analysis of management needs over a long period, as well as during the immediate installation. He must be able to understand electronics in terms of what the systems can do for the company, not merely as technical devices. Yet he must be able to understand the technicalities sufficiently as to be able to appraise coming improvements in the machines as they relate to company systems.

He must be a person who accepts and encourages orderly change.

Most important, he must have the confidence of executives. A major factor in building and maintaining this confidence will be the ability to communicate effectively with all levels of management and of operating personnel.

If he himself is not a technician—a scientist, engineer, mathematician, programmer, etc.—he must be able to communicate with each of these in his group. (Even if he is a technician, it may be difficult for him to communicate with men outside his own field.)

Support—Budget. Once selected, the head will need continuing support. For example, it is pointless to establish a group unless the budget recognizes the fact that salaries for the necessary experts in this field tend to run higher than companies have heretofore experienced (unless they have hired expert chemists and research engineers,

for example). Moreover, the group requires adequate allowances to attend computer schools and conferences, to visit installations, and so on.

Support—Internal Attitude. A major problem for the executive is to create a favorable environment in the company. Without this the team cannot operate effectively. The group must be able to understand the need for certain types of information, and in particular be told of the various exceptions which occur so infrequently that only experienced personnel know of them. Without cooperation, the group will not learn of these exceptions until they occur. By then it may cause considerable difficulty to weave means for handling them into the system.

Most firms are assuring their employees that no one will be discharged because of any innovations. But this is only a beginning. The status of many employees depends upon the fact that they are the only ones who understand certain routines. Now the need for this ability, acquired painfully over many years, is to be eliminated. While the elimination of dependence on particular humans may be desirable from the viewpoint of the company, it seldom will be welcomed by the employee unless he has reason to believe that his job will be enlarged.

As industrial psychologists have learned, mere wage assurance is not enough. When the company says to the employee, "If you help us obtain our organizational goal, we'll help you attain your personal goal," the workers tend to lose interest in their work and do only the minimum that seems to be expected of them.

Real acceptance depends upon group participation in working out the changes which are going to affect them. The change then becomes something that the group does, rather than something which is done to them. This point is of such importance that it will be given further consideration in the next chapter.

Administration of the Group That Selects the System. The executive who administers the program for selection of an electronic system cannot take time to understand all of the technical details. He should not try to make all the decisions. Rather his role is to ask discerning questions, to make sure that the study group has made a thorough investigation and has logical reasons for each of its recommendations.

The questions can be grouped into four major areas which the executive may consider. These areas are:

- A. Potential applications.
- B. Selection of appropriate electronic system.
- C. Economic feasibility of various alternatives.
- D. Managerial aspects.

Because every company has its own problems, the relative emphasis given to the following questions will vary. The list can be viewed as a basis from which the executive can develop the discerning questions most suitable for giving direction to his group, to assure himself that the necessary studies have been made.

A. Potential applications.

1. Have all areas been examined? (See Chapters 4, 5, 8, 9, and 10.)
2. Which areas seem to offer the greatest immediate benefits, and why? Which offer benefits over the longer term?
 - a. How has the effort of the study group been allocated, as between areas in No. 2, and why?
 - b. What is the condition of the company's present data-handling system? Is it up to date? What is required to prepare for conversion to an electronic system? (See Chapter 9.)
 - c. Are there any areas in the company which should be analyzed scientifically? Can such a study provide a basis for an electronic system? (See Chapter 6.)
3. Have any trial applications been tested on a rented computer? What were the results?
 - a. What has been the experience of other companies? (See Chapter 4.)
 - b. Has any other company applied new methods of analysis to a study of these applications? Did the results of the study affect the selection of an electronic system? (See Chapters 6 and 8.)

B. Selection of appropriate electronic system.

1. How was the scope of the system determined? (See Chapter 3.)
 - a. What are the advantages and disadvantages of large-scale general-purpose systems for this company's situation?
 - b. What are the advantages and disadvantages of medium size general-purpose systems for this company?
 - c. Are there applications for special-purpose systems?

- d. Where do combinations of *a*, *b*, and *c* appear more suitable, at least for the present, and why?
 2. What types of components are required? (See Chapter 3.)
 - a. What inputs are required? Are they available, or when will they be available?
 - b. What processing units are required?
 - c. What types of storage are required?
 - d. What output devices will be necessary?
 - e. What components are required for integration, by using similar media at various input points?
 3. Which components are available? (See Appendix 3.)
 - a. What new components are under development by manufacturers? When available?
 - b. Should the company sponsor the development of new components?
 4. What is the basis for choice of equipment suppliers, other than cost?
 5.
 - a. What is the record of the supplier's equipment as to dependability, accuracy, and flexibility?
 - b. What services does the manufacturer offer? Training? Programming? Maintenance? Other services? What is the background of his representatives?
 - c. What is the financial status of the supplier? What assurance is there of continuity in provision of adequate service and development of better equipment?
- C. *Economic feasibility of various alternatives.*
1. What is the estimated cost of operation of various alternative systems? (See Chapter 5.)
 - a. Did the cost calculation include:
 - (1) Equipment installation (air conditioning, space conversion, etc.)?
 - (2) Programming?
 - (3) Training?
 - (4) Change of operating procedures, including analysis to design and install integrated systems, develop new reports, etc.? (See Chapters 8 and 9.)
 2. What is the cost of present systems? What would the cost be if present systems were made more efficient by using methods other than electronics?

3. In what ways will savings be achieved?
 - a. Clerical costs? Machine costs? Reduced investment in assets? More effective management decisions?
 - b. What are the major assumptions made in calculating savings?
 - (1) When must more personnel be hired to prepare programs, etc.? When will personnel be shifted from other duties?
 - (2) When can delivery of the equipment be expected? What has been the experience of others?
 - (3) What effect would delay in delivery have on saving anticipations? What would be the cost effect of delays due to difficulties in programming?
 - (4) How long will it take to test the machine? To trial-run programs? Where can older equipment be dropped?
 - (5) In what priority will applications be placed on the new system? Why?
 - c. What are the costs of relocating and retraining displaced personnel? What effect will this have on anticipated savings?
 - d. What effect will expansion or contraction of the company's business have on the potential savings?
 - e. Would systems under development, if successful, make the chosen equipment economically obsolete?

D. Managerial aspects.

1. What organizational changes are required before the electronic system can be installed?
 - a. What should be the organization for the computer?
 - b. What impact will the installation program have on the present organization for data processing? For data analysis?
 - c. Were the views of representatives of all functional areas considered?
 - (1) What arrangement was made to obtain cooperation from experts in the operations of the various functional areas in the company?
 - (2) What were the most significant suggestions made by each of these representatives? What advantages did

- they see in their particular areas? What difficulties? What data do they need? What do they want?
- (3) What has been done to orient personnel other than the representatives? What are the attitudes of these other personnel forces?
 - (4) What are the data requirements of top management?
- d.* How will the company's organization structure be affected?
- 2. In what way will the service or product sold to the company's customers be affected?
 - 3. How will the auditing, legal, tax, and similar requirements be affected? Will prior approval be required?
 - 4. What continuing effort is required for further development of the electronic system?
 - a.* What cooperation should be afforded with other users? What industry groups?
 - b.* What suggestions can be made to manufacturers to improve equipment for company purposes?
 - c.* What use should be made of consultants?
 - d.* What support should be given to basic research in this field by universities, etc.?

Measurement of Requirements. Choice of the best electronic system calls for more than mere selection of a certain machine design of particular characteristics or degree of reliability, etc. The quantitative measurement of the business information requirements is a fundamental problem. Such requirements must be determined before a choice can be made as to which system will perform the work at the most economical price.

Few companies now are in a position to set forth their data requirements in sufficient detail for selection of electronic systems. In addition, few large-size and medium-size companies have developed their system of management planning and control to the degree where the information uses can be integrated with machine capabilities.

Machine Selection. Machines now available can process certain types of business data economically. But special abilities may be necessary in specific situations. For example, a company may only need to obtain certain information rapidly and on a daily basis. It should select a special-purpose electronic system that can process and

report data rapidly. A general-purpose computer might be used for this if it has sufficiently fast access to large volumes of memory, but it might not be economical. Another company may require rapid preparation of reports for management action. The electronic system selected should provide fast sorting speeds, fast comparisons, and sufficient print-out.

When large amounts of simple computations are necessary, with a minimum of requirements for printed outputs (such as in scientific work), a computer can be selected on the basis of speed of computation, accuracy, and reliability. If large print-out is required, e.g., payroll checks, billings, etc., then a system can be selected that provides printers with sufficient output capacity and speed to perform the job. If faster billings will increase the turn of accounts receivable, and thereby provide the company with additional working capital, then faster and more expensive print-out units may be desirable.

In some cases the problem may be to have access to the data from geographical distances. For example, in a system now operating, a central warehouse has a number of district offices order upon it. Formerly, by the time requests were mailed and returned the customer might become dissatisfied. The central warehouse is replenished from a production facility which is many miles away. The electronic system installed was one which provided multiple inputs and outputs at each of these locations, thus providing the rapid communication required.

Dependability and Accuracy. Several aspects of dependability and accuracy merit consideration. By and large, an electronic machine usually is dependable. It rarely errs if it is in proper working order and is not called upon to do more than the routine job for which it was designed.

The larger the machine, and the more comprehensive the scope of its activities, the greater the danger that there will be trouble if it does break down or make a mistake. Not only are more operations affected, but usually a large machine is not so easily replaced as a person or a smaller machine.

Experience with electronic machines so far has indicated that the machines are sufficiently dependable for everyday use. Certain precautions in the way of maintenance and stand-by equipment seem advisable, but in general this is not a major problem.

Most executives would like to see a specific machine operate successfully before ordering one for themselves. It is the most satisfactory

test of dependability in their eyes. Unfortunately, as already indicated, there are difficulties with this approach. The equipment now offered is not as good as the kind which engineers believe can be produced some day. Yet a company may find itself in an adverse competitive position if it waits until other companies experiment with present machines and thus get too much of a head start. Moreover, because of the need for a special approach to each company's individual problems the equipment that proves able to work well for one may not be entirely suitable for another.

Several suggestions have already been made to meet the problem of dependability of specific equipment. Major manufacturers will no doubt have spare machines available—not necessarily locally—so that if a machine breaks down, another, perhaps several states away, can take over. The data may be fed to the distant machine by wire, or tapes flown to it, with small loss of time. Several tests of this type of operation have already been conducted, with generally favorable results.

As for possible loss of a whole set of data, the solution proposed is to keep separate sets of tapes onto which the situation can be read off at intervals. A disaster at the computer would only necessitate a backing up to the last read-off point, and starting over again from there, reusing the inflow of data from then on. Since these storage tapes can be prepared without interrupting the operations of the computer, and since they can be reused when the data are no longer relevant, the cost will not be substantial. This is not considered to be a major problem.

The accuracy of electronic equipment is remarkable, considering the volume of items processed. In several carefully monitored test runs, such as the Bureau of Census, many millions of transactions have been handled without undetected error. In other installations errors have occurred at the rate of only a few a month. By and large, electronic accuracy is an asset, not a problem.

Efficient Programming. Programming skill is very important. Though the machines operate rapidly, if they must repeat a computation many times, the total difference in time between two methods of accomplishing the same thing (and therefore the cost) may be substantial. On the other hand, experience has also shown that the law of diminishing returns holds in this area. Obtaining the last bit of efficiency is usually the result of considerable human effort, which is justified only if there is considerable repetition of the routine.

A partial offset to the cost of programming is the fact that a "library" of prefabricated, checked routines can be built up for certain purposes. In some cases these programs are now being supplied by the manufacturer of the computers. Another development in this direction is the emergence of "pseudo" codes. In effect, the computer will be asked to do its own coding. The original instructions will be in forms more familiar to the ordinary business analyst, and the computer will translate them and amplify them into the coded program necessary to conform with its particular design characteristics. So far there has been some development of this concept, but more seems inevitable if manufacturers are to achieve widespread acceptance of their machines.

Installation Costs. The factors which should be considered in estimating the potential costs of any mechanical installation—maintenance (often supplied with rental by manufacturers), space requirements, staff, supplies, and so on—are typical of costs for an electronic system. Of these, the staff is likely to be most important, after the basic cost of the machine itself. Good analysts will get salaries well into five figures, good programmers almost as much.

The costs of the preliminary studies and of the initial capital investment are not in the range required for a desk calculator or typewriter. The less expensive electronic systems cost at least \$25,000 to buy. The larger systems cost more than that per month to rent.

Estimation of potential clerical-cost savings that may be provided by electronic systems is not an easy task. Because of the state of the art, the knowledge of electronic systems required to establish savings computations is often difficult to obtain. Savings considered should not only be those to be gained by using the machines now available but also savings from machines which are being designed and developed, since new designs are rapidly becoming available.

Cost comparisons should take into account the cost of changing programs, subroutines, and coding in case of adoption of a still newer machine in the future. Manufacturers hope that they can develop an automatic conversion device for translation of instructions between machines, but these are not yet available. As pointed out in Chapter 2, extensive programming and coding for use on new equipment is expensive.

Obsolescence. The rate of obsolescence is difficult to determine. Some manufacturers of electronic systems believe that a two-year pay-off is a sufficient requirement for a successful installation. However,

as has been shown, clerical-cost savings may be a minor factor in evaluating an electronic system. In such cases obsolescence is less of a problem.

The design of most large-size computers now offered has not changed radically in the last few years. Current developments in computer laboratories are nearing new technological breakthroughs, particularly with regard to certain components. However, installation of these components will not always affect all parts of the system, so again the risk of obsolescence is somewhat lessened.

Investment Alternatives. Alternatives available to the businessman include consideration of large-scale computers, intermediate-speed computers, and special-design electronic systems. All three are presently available. The intermediate-speed, or "medium-size," computer is less expensive, but has limited capacity in input or output components, as well as in speed of computing. Generally speaking, the larger systems have over ten times the speed and more effective flexibility than several of the leading medium-size computers. Special systems, on the other hand, may approach the speed of large-scale computers for their specific operations. Though special systems are limited in use, yet in some instances it may be wise to select a special electronic system that has a quick pay-off. This choice could give the company experience in electronics and also provide time to judge the developments which will be available in the future.

Savings Estimate. An electronic system may create clerical-cost savings, but still may not always be desirable. There have been instances of companies in smaller communities that transferred some functions to other localities and as a result have been subject to difficulties, such as union action. Also, the savings may not be realized as soon as estimated.

Much can be done to prepare for the computer, as was pointed out in Chapter 2. A company can start to reduce the clerical-labor pool for certain operations through labor attrition, even before the delivery of a machine. However, there are certain clerical operations, like billing, which have to be kept up to date and cannot be postponed.

Savings are often available without installing a computer. If the data output is not needed, the routine should simply be dropped. It should not be placed on a computer merely because it can be done faster and cheaper. Input data may be unnecessarily detailed for the desired output, in which case a computer is not required if a simple

method of gathering the data is available. To use such savings in determining computer investment decisions may result in a wrong conclusion.

In other situations, a computer might handle the peak load of seasonal work, but it might not be economical to have it available the year around. A solution may be to send seasonal work to one of the computer centers which are being established by various manufacturers. Consideration of these alternatives is essential to determine if and when a computer should be purchased or leased.

In spite of the many alternatives involved, the experience of a number of large-size companies has shown that there are usually at least one or two clerical applications which can justify the investment in an electronic computer. Additional savings can be realized through faster management reporting and from the solutions derived from the newer mathematical decision tools.

If a company wishes to secure the advantages of better decision making, it is not enough merely to study the application of computers to their clerical system. They can also realize profits that are just as tangible and often far more substantial, through application of electronic systems to the needs for better management planning and control.

Conclusions. The selection and installation of electronic systems in a manner which takes full advantage of new developments are major undertakings. The technical requirements, both of the electronic systems and of the company's needs, make it necessary to use a team approach.

The task of the executive is to obtain the assistance of the proper experts and to evaluate their recommendations. For this he requires some understanding of the general capabilities of electronic systems, and of the requirements for everyday operations and for management.

The actual selection of a computer is only a part of the problem. Too often it has been treated as though this were the major, if not the only, executive responsibility.

To obtain the full benefits available from use of electronics, it is desirable that the executive assume more responsibility than has been necessary for the installation of previous data-handling and communication equipment. Only men with broad understanding of a company can assess the over-all impact of the new systems.

CHAPTER TWELVE

The Challenge to the Executive

We cannot turn back the clock, and it would be futile—in fact, disastrous—to attempt to do so. As I said before, the law of life for institutions, as for living species, is adapt or perish.

. . . much work lies ahead for you to do. To meet the changing conditions of this rapidly moving world, management needs new tools for use in the making of policy decisions. The challenge before you is to use your imagination and specialized knowledge in devising the new tools that are required.

“The Challenge of Industrial Change”

An Address by Robert B. Dunlop

President, Sun Oil Company

Automation, electronics, new methods of analysis, new concepts of planning and control, and the other developments discussed earlier, together present a challenge to the business executive. The challenge exists both within his company and in the social environment.

Sufficient applications have been made so that a pattern already has begun to emerge. The new tools are relieving the human mind of the need to perform routine tasks, wherever policies or methods can be fairly well established in clerical and production operations. Combined with new methods of analysis they are beginning to take over some middle-management decisions.

Many executives still have shown little interest in the subjects of electronics, mathematics, automation, and so on. Pressure of regular work is such that these executives feel they have little time for consideration of future developments which may not apply to their companies.

This attitude may be justified. However, it seems likely that the advent of these new tools and concepts is going to change the nature

of competition in many fields. Both large and small firms may have to adjust to the new circumstances if they are to survive. In the past a major advantage of smaller firms has been their flexibility. They could quickly change their service to meet individual customer demands, whereas larger firms of necessity often were committed to set lines of action. Much of the trend toward decentralization among larger companies has been traceable to the attempt to achieve some of the flexibility of smaller companies.

In the future, however, if integrated systems are achieved, size may become an advantage for flexibility too. The larger companies, using electronic communication and controls, may be able to move quicker than their smaller competitors, and at less cost.

To achieve such integrated systems, including automation, will be expensive in some fields. In fact, though they are far from small by some standards, it already seems as though the newly merged "smaller" automobile companies may find it increasingly difficult to compete with the giants in their industry. General Motors, Ford, and Chrysler are thinking in terms of billion-dollar change-overs.

Recent trends in industry have been toward less use of smaller suppliers in some lines. With automation the trend may be expected to continue. A large manufacturer recently installed a highly mechanized shop to build the "bits and pieces" which it formerly bought outside. It makes the items to production order. Although the cost of producing the items is somewhat higher than buying, the company believes that this is more than offset by inventory savings and avoidance of parts shortages.

An alternative that appears to have a chance of countering this trend is the development of less expensive electronic systems for data processing, and less expensive control systems for automation, which smaller firms can use. Certain electronic designers and manufacturers are working in that direction. The extent to which potential users will encourage such developments remains to be seen.

Though a pattern of change may be evident, it is also apparent that the process has hardly more than begun. Developments are scattered. One firm is putting some clerical operations on a computer, another is investigating automation, a third is doing both in separate divisions of the company, a fourth is doing mathematical programming, and so on. Management faces a challenge to fill the gaps between such spe-

cialized efforts, and to relate the process of change to the objectives of their individual companies.

There is a question as to whether the best approach will be on an individual company basis or on an interindustry basis.

Executive Responsibility. However the development may be handled, it appears certain that decisions on important matters will be made by executives, not by the technical staff alone. Executives will choose among the various possible programs and will administer developments. They will determine the broader aspects of resource allocation, staffing, organizing, planning, and controlling. They will approve the choice of equipment, after making sure that a detailed analysis has been performed to establish specific requirements. Executives will monitor the process of the change-over, both as to its technical and its human-relations aspects.

Integration of Business Systems. A major problem, which has been discussed at length in previous chapters, is to integrate business objectives with the systems of automation, electronic data processing, and management planning and control. Although the need is recognized, the problems are far from solved. Knowledge in this area is inadequate. Compared to the size of the problem there still is not enough work being done.

Operating managers, whose interests are vitally at stake, usually are too busy with day-to-day pressures to have much time to study the integration problem. When they try to do this, semantic differences, lack of technological training, absence of installations they can visit for visual education, and, for some, inability to grasp fundamental mathematical relationships have served to frustrate their efforts.

Relocation and Retraining of Personnel. Personnel is another problem. Displacement of workers will occur. Some unions have already approved a resolution calling for labor-management-government control of automation. The turmoil caused by worker-management relations during the first industrial revolution serves to underline this resolution.

Some companies hope to solve part of the unemployment problem by shifting workers into other operations, after retraining, and by hiring larger numbers of maintenance men. They also expect that workers who understand the company processes will be needed to help with systems studies. In view of the new skills required, to prepare workers

for the change will be quite an undertaking. Some workers may be absorbed by equipment builders, but automation in electronics is far advanced.

A most serious challenge will be to make sure that workers in automatic factories and offices continue to feel they are making a real contribution. This already has been a major problem, even without automation, as shown by Mayo's famous experiments at the plant of Western Electric.

Administration of Research and Development. Administration of the necessary research and development will be still another consideration. Evaluation of long-range, far-reaching research studies has seldom been of major concern for most executives, except in the chemical, electronic, petroleum and similar industries. Fundamental research work has been done by the government and universities, for the most part. But it seems apparent that continued development in the fields of management, automation, and data processing must depend upon research activities by business itself. The scientific worker needs to experiment and observe, to test his theories. While some of these tests can be carried on in the simulated offices, the best laboratory will be an actual business operation.

Some firms have already recognized this. However, by and large, few executives have shown that they really understand how to administer fundamental research. Many of the office-equipment manufacturers had to acquire smaller electronic companies in order to enter the computer field. Much so-called research in this country actually has been development engineering, attempts to reduce costs of known operations, rather than an attempt to take a fresh approach, a study of fundamentals.

The effectiveness of such long-range research is often questioned by businessmen accustomed to monthly statements of progress. Fundamental research can solve problems by bypassing them, with a sudden spurt, after long periods of seeming lack of accomplishment. Such changes can revolutionize an industry before old-line management stops making buggy whips. An example would be in aircraft propulsion, where American leadership in gasoline-engine technology was the basis for some complacency until Korean War experience showed that the Russians had bypassed the problem with jets.

Should a company research group be encouraged to start with the top, with broad, over-all objectives? Or should it start at the bottom,

with specific bottleneck problems which, if solved, would provide immediate pay-offs, and at the same time give the company a chance to learn by actual experience with new tools and methods? There are a fairly large number of companies whose efforts to date show little evidence that the problem has been properly considered. They have no program which encompasses the needs of the firm and the objectives which the research and applications are to serve. Nor has there been proper scheduling, to determine the specific persons who should comprise the research group and when they should be hired, the necessary resources and when they should be placed at the group's disposal, and so on. Feedback to various executive levels is often weakest of all. When executives are not familiar with the type of work that the research team is doing, sometimes the team can wander far off the reservation. To give research considerable freedom, but not license, calls for nice executive judgment. Possibly the worst way to control a research effort is one which nevertheless is frequently used—to require overelaborate budget justifications.

Installation of Electronic System. Executives eventually will make the decision whether to install presently available equipment, or to wait for the appearance of improved models of electronic systems or improved automation. Adding to the difficulty is the fact that most manufacturers of equipment have backlogs of orders, so that the time factor is given extra significance. Although not likely as a general rule, it is possible that in given situations, by the time an order has been filled, the installation completed and de-bugged, etc., much of the system may be technologically obsolete. There may be resultant advantages to competitors who waited. On the other hand, there often will be substantial competitive advantages from being first with an improvement over present methods, even though the installation may later be subject to improvement.

Developing Interest. The first problem in furthering a new idea usually is the difficulty of interesting others in its development.

Although relatively few companies actually have installed large-scale electronic systems or have made substantial use of the other new tools of management and production, this does not mean that there is little interest in these subjects. The reverse is true. In fact, it can be considered as a tribute to the alertness of American management that the challenge of the new developments has been so generally recognized. Almost every major company has at least a few individuals who

are actively studying these areas and trying to relate them to their particular organization's requirements. Some companies have been studying the problem for over five years.

There has been little pattern, however, as to who in the organization the people might happen to be. In some cases the president of the company has initiated the studies, having learned of the new concepts through his connections with such groups as the board of governors of a university or of a research organization. Or he has learned of them from other executives. In other companies, interest has started among a few young men in such places as the industrial, engineering, accounting, or systems and procedures departments.

Professional Organizations. Associations with allied interests, such as the Controllers Institute, The American Management Association, The American Institute of Accountants, the American Accounting Association, the National Association of Cost Accountants, the Internal Auditors, the Machine Accountants, the Systems and Procedures Society, and others, have encouraged their members to study these new developments and have pointed out the significance that the developments will have for their work. As shown in Chapter 6, several new organizations have been founded—Operations Research Society of America and the Institute of Management Sciences. Their purpose is to enable researchers to exchange information and to promote new concepts. The engineering societies also have been very active in this work. The material presented by these groups has been given close attention by many company executives and has resulted in the initiation of activity.

Informal groups of interested businessmen are meeting on a regular basis in a number of cities. Attendance is limited to one or two participants from companies actively engaged in operating or installation studies. No minutes are kept, so that discussion of problems will be as free as possible.

An example is the Business Electronics Round Table in New York City, brought together by Harold Cauvet of General Foods.

Full-time Assignment. As the potential of new tools and concepts came to be realized, interest has been formalized by assignment of personnel to study and to recommend potential applications for the company. Gradual acceptance, while it takes time, may be necessary for many companies, especially where operating executives are unfamiliar with electronics and mathematics. In one company, for ex-

ample, a research study was undertaken several years ago by order of the president, who had been alerted to some electronic developments. The effort was largely wasted. Apparently this happened in part at least because the company organization and the outside consultants did not know how to cooperate effectively at that time. The company dropped the project temporarily, but now has revived its interest and has a large, active research project staffed with full-time company men and hired experts. The relationship with the consultants has been renewed.

On the other hand, some lower-management personnel have become interested in these fields but have found that they could not get attention from top management. Frequently this has resulted in the movement of these younger men to other companies. The younger executives have attended schools and meetings on their own time, have met interested executives from other companies, and have been hired away by these other executives. Sometimes this has happened at the least hint that the young men were available, a circumstance indicative of the intense pressure to find capable men in these new areas.

Sometimes operating personnel have led the way. In some companies it has become evident to operating managers that the volume of paper work and other detailed activities required to carry on the business was increasing at such a rate that the situation would get out of hand in a few years if something were not done about it. For this reason these companies, some of them in industries seldom thought of as leaders in management research, have been in the forefront of the investigation of electronic systems.

Equipment Manufacturers. Manufacturers of electronic equipment have been eager to assist in this process, but the effectiveness of their efforts is somewhat difficult to assess. In a few cases the electronic data-handling systems apparently have been oversold, and already there have been rude awakenings. In other cases executives have attended manufacturers' computer programming schools and have come away with great respect for the machines but without the ability to see how the machines could be used to advantage in their own companies. Nevertheless, manufacturers have been the best source of information.

In general, most progress has been made by those companies which have assigned staff members full time to research study of the new systems and of the company's particular requirements. Executives in

these companies usually wish they had undertaken full-time effort at an earlier date.

Obstacles. A number of obstacles still confront the company which has organized groups to study potential applications of electronics and mathematics.

Resistance to Change. Resistance to change can be expected in any company. The difficulty of rerouting any document, reassigning any duty, and regrouping any organizational unit is such that executives frequently have refused to install a change that is demonstrably an improvement. The benefits are not considered to be worth the trouble involved.

Obviously the impact of applications of electronics or of mathematical decision methods will rarely be minor, and may be so great as to merit the designation of "revolutionary." Those workers who remain will have to learn new skills, accept new responsibilities, make new personal adjustments with new associates, and accustom themselves to working under new controls. In addition to the workers, executives will be more affected than has usually been the case in the past. The new electronic systems are expected to reduce the number of workers with whom some executives deal. The new methods are expected to change many executive activities. It is well recognized that most employees, even at the upper executive levels, tend to dislike closer controls, even when they do not actively resist them. The management which attempts to use new communication and analysis methods as a club to force better performance from subordinates is almost certainly going to face resentment and other difficulties.

Performance sometimes has been so much improved by a particular installation of automation, or of electronic data processing, or of mathematical-analysis methods, that it caused resentment in those departments which did not receive the installation. This has led to pressures from these neglected managers to have similar aids given to them even though there was not sufficient basis for expecting similar results in their type of operation.

Extent of Research Required. Research into a particular firm's needs has been found to be a slow and difficult task. Investigators have to have a passion for detail. Each company has its own marketing structure, its own products and its own methods of making them, its own organizational structure, and so on. These have to be understood and measured to a degree of precision seldom before attempted.

For example, it is only recently that some companies have begun to realize the extent to which individual departments seem to have a "personality" of their own. Practices that work successfully in one department may have a completely negative effect when applied to another, even when it is engaged in similar functions.

Diversity of Attitudes. A major problem for the head of a research group has been to reconcile the differences in attitudes between the various members of the team, and to interpret these attitudes to line management. Contrary to some public superstitions, good research workers are not necessarily temperamental, but they sometimes have been impatient with a manager's delays while he assures himself of the feasibility of a program.

Equipment Limitations. Moreover, the electronic systems now available usually do not have logical systems based on the logical patterns of a particular business' needs. Though the machines are adaptable enough so that they still can give considerable service and therefore justify their cost, careful selection of equipment, with re-design of certain components, sometimes has been found necessary for optimum performance in both clerical and production operations.

Cost. The greatest obstacle has not necessarily been the cost. Even with ample funds companies have found the above difficulties may hinder effective action. Certainly, however, cost is a major consideration. None of the machines and none of the trained personnel can be found on the bargain counter. Since the principle involved in almost all of these applications is the fact that the whole system becomes involved, sooner or later, it follows that very inexpensive, small-size applications are almost nonexistent or trivial. Computers are not cheap, and a very "small" linear programming problem is likely to be not much more than a statement of the obvious.

Significance of Decisions. The decisions that executives make now on these matters may well set a course of action for a business for a long time to come. The history of our industrial corporations is a neglected field, but evidence is beginning to show that certain types of decisions are vital for the long-range prosperity of a company.

In the past, decisions of this vital nature frequently were concerned with territorial considerations. For example, John Wanamaker recently abandoned the store in New York. In describing the event, business publications laid a major share of the blame to a decision made by executives two generations ago. The management at that

time was faced with the choice of expanding where they were or of moving farther uptown. They chose to expand in a constricted market area.

It may well be that failure to develop an integrated business system or development of one oriented to the wrong objectives may result in such competitive disadvantages that recoupment may be just as difficult as it would have been for Wanamaker to move its store into a more favorable shopping area.

Mere correctness of the major decision may not be enough. Executive maturity will be needed in handling the host of problems which will accompany the change. The problems are not solely internal; there are major social consequences which they must consider. Coordination of company developments with the activities of other groups in our society will become increasingly important.

THE CHALLENGE TO SOCIETY

The challenge to business leaders is broader than that within their immediate companies. Coming changes may alter the entire structure of business and social relationships. In recent years there have been numerous expressions of the need for businessmen to demonstrate statesmanship to meet growing social problems. The advent of new automatic systems that can reduce certain work-force needs by a factor of 75 per cent obviously will create a new social problem, large enough by itself. But in addition to this, the talents required of those workers who remain will be altered. The nature of the products, the marketing channels, and so on, also may be different.

Rapid change-over in all or many of these would present a serious challenge to our society. Articles and editorials already have focused attention on the possibility that large numbers of employees may be displaced by automation of the office and of the factory. In general, the danger that they describe does exist. But it is not necessary that the change-over should be calamitous or even particularly disturbing. There are a number of problems which must be solved, but there is no disaster which must be accepted.

At the same time, the difficulties should not be ignored.

How fast can automation be introduced without disrupting society? At what rate can capital equipment be replaced? Present rates vary

from 8 to 15 per cent in different areas. Since it may take 5 to 10 years to develop equipment and techniques to the point where they will be technologically available and economically feasible in many lines, the change need not be abrupt. A speeding up of the rate is rather the most likely prospect. Considering all factors, such as the current shortage of trained personnel, the high cost, and so on, it appears that though automation of the office and factory is certain to come, it will not come overnight. This period of delay will give businessmen a chance to program the change, so that should a surge of effort in this direction become inevitable, plans will have been laid as to the best way to cope with the situation.

Orderly Change. The change-over to new tools and new methods can be orderly. The tools and methods themselves can be used to help business leaders prepare better long-range programs than most of them have ever achieved before. The programs can take into account the social impact of decisions, as well as more commonly used estimates such as demand for product, and cost expectations. Social factors are true profit considerations, not benevolences. History always has shown that if society is badly disrupted, no one profits except occasional opportunists.

Companies can gear their installations to maintain a progressive economy. For example, diminished hirings need not be permitted to affect a community without adequate warning. Workers can be told that if they leave, they might have to seek different types of jobs. They can be given training in advance.

Stockholders and the capital market will face new problems of evaluation of securities. Executives can help them consider the over-all impact of new financing ventures. If adequate information is made available, more informed financial judgments will be possible.

Most companies in the forefront of new developments apparently believe that their owners can be brought to understand the desirability of expenditures for such purposes. So far, companies like Metropolitan Life, Burroughs, and General Electric have given considerable publicity to their efforts, including in some cases a description in their annual reports.

As part of the process of change, businessmen can keep the public informed of their plans and activities. The last two decades have taught business leaders the value of business statesmanship. They

have learned that it is dangerous not to consider social consequences. It is also difficult to prosper in a society that does not understand or appreciate what they, the business leaders, are trying to do.

Business Statesmanship. Business statesmanship is a development of the last generation. There has been a tremendous expansion of health plans, of pensions and other employee benefits, of profit sharing, and of attempts to stabilize employment the year round. Increased use of professionals, such as accountants and lawyers, has been another influence.

Businessmen who believe that free enterprise can continue to develop the best institutions, the most effective production systems, and so on, have the responsibility for seeing that the new machines and methods are used to best advantage, at a minimum cost to society.

In particular, they can take up the burden of research. So far, as indicated, the development of new methods and machines has been sponsored primarily by the Federal government. If our free institutions are to survive, it seems logical that business also must be willing to undertake basic investigations which will benefit all.

Companies can do this either directly, in private research groups, or by sponsoring projects at universities. At UCLA, Harvard, Carnegie Institute of Technology, University of Chicago, and many other institutions, research groups will not undertake an investigation unless results can be made public. Even a secret operation, such as the Air Force's RAND Corporation, eventually permits its workers to publish many of the methods and principles which they develop.

Education for Management. As technology has become more important to business firms there has been an increased tendency for technicians to become managers. It can be expected that this trend will continue. Training in electronics and mathematics should enable engineers and scientists to become even more important to the firm of the future. However, although individual technicians have been brilliantly successful, the trend poses a general social problem. By and large, both by training and early experience, most engineers and scientists are not always able to deal with human factors, with intangibles, and with over-all concepts. The technician is trained to deal with fairly exact knowledge, as opposed to opinions, which are taught in the humanities and social sciences.

As long as management must deal with risk situations, with large areas of uncertainty, a straight engineering approach will not be ade-

quate. Yet, at the same time, so many tools and methods for better decision making are being developed that the intuitive hunch player in management should usually be at a serious disadvantage in most situations.

It appears that a new type of training may be required for future managers. This poses a serious problem for our educational system. There are inadequacies at all levels. Some experts are coming to believe that a completely fresh look at our system of education may be required.

In the past few years there have been warnings that Russia is turning out twice the number of scientists and engineers that the United States is training. But the Russians have gone farther than merely to increase the number of their engineers—they have established a different process of selection whereby grammar-school students are examined, and those students who show ability likely to respond to technical education are separated into different groups and given a special training.

Whatever one may think of this practice, it is a partial answer to the complaint voiced in American universities that high-school graduates are mathematically and scientifically illiterate. It is not enough for Americans to scorn the Russian system. If the need for technicians continues to grow, we shall have to make some effort to encourage more students to take this training.

But mere numbers of scientists or engineers is not the whole answer. Nor will greater quantities of students, trained by our business schools in the traditional "art" of management, supply the need for executives capable of dealing with the new tools and concepts. A new curriculum may be required, one designed to meet the different demands that a different type of society imposes. The combination of electronics and data processing, of mathematics and management decision making, and automation, all together in an integrated system signifies nothing less than a bringing together of the social, the life, and the physical sciences. This is a new concept, one which is only beginning to be recognized.

Social Consequences. The first industrial revolution changed the pattern of human life in many ways. There is reason to suppose the changes which will follow the second may be fully as great.

Most certainly the use of new tools and methods will increase productivity—they already have. To what extent productivity will be

increased no one can say for sure, but when installations already made, using tools that admittedly are imperfect, can cut the number of workers to a quarter or a tenth of those formerly employed and yet turn out more and better work, then the increases are likely to be spectacular.

Nor do these developments leave us with a limit to further progress. Quite the contrary. In the past each manager had to learn "by experience"; the art of management was taught primarily by apprenticeship. Formal learning was based primarily on routine uses of certain tools such as accounting and statistics, and a few generalized principles, hesitantly recommended.

Much of the "art" of management will always remain, presumably, but now we have the hope of developing whole areas of descriptive, predictive, and decision models. Model building can be taught. From these models further progress can be made so that, as in the other sciences, one generation can build on the work of its predecessors.

Education may have to be changed, as the student pursues the life, social, and physical sciences. But a more productive economy should be able to support students both out of and in the plant for an additional period. College education may be as common as high-school education is today. Better students may go on to advanced work and research as a matter of course. In-plant training can also be more extensive than it is.

The new developments are of immense significance for the so-called backward areas of the world. By learning the new techniques and installing the new tools these countries may be able to skip a whole industrial generation and enter directly into the technology of the last half of the twentieth century. If they had been forced to rely instead on their cheap manpower, they would always tend to lag a step behind their richer neighbors.

Increased emphasis on the scientific approach will not be confined to the management of business. Attempts to achieve more accurate observation and measurement already have been made in other fields. Economics has seen such advances in this type of work that a new term, "econometrics," has been coined to describe the activities. Sociology has a similar term, "sociometrics." Medicine is changing to adopt the new attitudes, as are other fields, and this trend should continue with accelerated force.

Problems will persist, of course. It may be difficult to keep people

busy in occupations which maintain their self-respect, when only a part of the population can turn out most of the products that are required. But human wants appear insatiable, so this may not be of too much concern. As indicated earlier, the transition stages should be the most difficult. And such problems as the increase in numbers of our older, retired workers no longer need be a problem.

A great boon to humanity will be the ending of the need to perform dull, repetitive clerical and mechanical tasks. As the first industrial revolution relieved our muscles from tasks too heavy or too wearying for them, so the second will relieve our minds from tasks that dull and deaden. As Norbert Wiener has said, we shall see the "human use of human beings."

L'ENVOI

And the Pursuit . . . No possible advance in our way of life is worth the loss of our liberty. The new tools and methods will not be an unmixed blessing. They will provide a means for a centralized control of human activities unlike that ever experienced before. Many of the devices in Orwell's *1984* are far from fantastic. Some are already here. Misuse of them, unfortunately, is also far from impossible.

Moreover, neither an enriched life nor liberty can assure happiness. In this increasingly complex society, no man can be an island. Men are bound to each other by their search for material wealth, their need for social contacts, their fear of foreign dangers, their drive for scientific achievements, their longing for artistic conceptions. Men spend the best hours of their days and the best years of their lives for these.

Yet these are not enough. Without spiritual content, they are meaningless.

Men can achieve much, in a material and conceptual way, through integration of their efforts. But spiritual value each man will achieve alone.



Bibliography

In the following bibliography the references are placed under four major headings:

- A. Background Reading for Management Planning.
- B. Electronic Systems and Their Applications.
- C. Management Sciences—Operations Research.
- D. Automation.

In most cases the authors cited have published a number of other articles or books. References to these will usually be found in the publications listed here.

A. BACKGROUND READING FOR MANAGEMENT PLANNING

1. Books

- Barnard, Chester I., *The Functions of the Executive*, Cambridge: Harvard University Press, 1938.
- Dale, Ernest, *Planning and Designing the Company Organization Structure*, New York: American Management Association, 1952.
- Dean, Joel, *Managerial Economics*, New York: Prentice-Hall, Inc., 1951.
- Drucker, Peter, *The Practice of Management*, New York: Harper & Brothers, 1954.
- Fayol, Henri, *Industrial and General Administration* (English translation), London: Sir Isaac Pitman & Sons, Ltd., 1930.
- Gardner, Fred V., *Profit Management and Control*, New York: McGraw-Hill Book Company, Inc., 1955.
- Goetz, Billy E., *Management Planning and Control*, New York: McGraw-Hill Book Company, Inc., 1949.
- Holden, Fish, and Smith, *Top Management Planning and Organization*, Stanford: Stanford University Press, 1948.
- Katona, George, *Psychological Analysis of Business Behavior*, New York: McGraw-Hill Book Company, Inc., 1951.
- Koontz and O'Donnell, *Principles of Management*, New York: McGraw-Hill Book Company, Inc., 1954.

- Mayo, Elton, *Social Problems of an Industrial Civilization*, Cambridge: Harvard University Press, 1945.
- Parker, Mary Follett, *Dynamic Administration*, New York: Harper & Brothers, 1941.
- Simon, Kozmetsky, Guetzkow, and Tyndell, *Centralization vs. Decentralization*, New York: Controllership Foundation, 1954.
- Taylor, Frederick W., *Scientific Management*, New York: Harper & Brothers, reprinted 1947.

2. Magazines

- Advanced Management*, Society for the Advancement of Management, 74 5th Ave., New York 11, N.Y.
- Business Week*, McGraw-Hill Publishing Company, Inc., 330 W. 42nd St., New York 36, N.Y.
- Controller*, Controllers' Institute, 2 Park Ave., New York 16, N.Y.
- Fortune*, Time Inc., 540 N. Michigan, Chicago 11, Ill.
- Harvard Business Review*, Soldiers Field, Boston 63, Mass.
- Journal of Accountancy*, 270 Madison Ave., New York 16, N.Y.
- Management Review*, American Management Association, 1515 Broadway, Times Square, New York 36, N.Y.

3. Other Sources

- American Management Association*—series on management.
- Controllership Foundation*, Management Planning and Control, An Annotated Bibliography, Controllers' Institute, 2 Park Ave., New York 16, N.Y.

4. Selected References

- Hurni, Melvin L., "Decision Making in the Age of Automation," *Harvard Business Review*, vol. 33, no. 5, September-October, 1955.
- Luce, Henry R., "A Speculation About A.D. 1980," *Fortune*, December, 1955.
- Rothschild and Kircher, "Projecting Capital Needs," *Journal of Accountancy*, September, 1955.

B. ELECTRONIC SYSTEMS AND THEIR APPLICATIONS

1. Books

General Books

- American Management Association*, "Electronic Data Processing in Industry," also "A New Approach to Office Mechanization; Integrated Data-processing through Common-language Machines," New York: American Management Association, 1955.

- Canning, Richard, *Electronic Data Processing for Business and Industry*, New York: John Wiley & Sons, Inc., 1956.
- Haskins and Sells, *Electronic Data Processing*, New York, 1955.
- Jacobsen, *First Conference on Training Personnel for the Computing Machine Field*, Detroit, Michigan: Wayne University, 1954.

Technical Books

- Engineering Research Associates, *High-speed Computing Devices*, New York: McGraw-Hill Book Company, Inc., 1950.
- Hartree, Douglas R., *Calculating Instruments and Machines*, Urbana: University of Illinois Press, 1949.
- Richards, R. K., *Arithmetic Operations in Digital Computers*, New York: D. Van Nostrand Company, Inc., 1955.

2. Magazines

- Automatic Control*, Reinhold Publishing Corporation, 400 Park Ave., N.Y.
- Computers and Automation*, Berkeley Associates, 36 W. 11th St., New York 11, N.Y.
- Control Engineering*, McGraw-Hill Publishing Company, Inc., 330 W. 42nd St., New York 36, N.Y.
- Data Processing Digest*, Canning, Sisson Associates, 914 So. Robertson Blvd., Los Angeles 35, Calif.
- Journal of the Association for Computing Machinery*, Association for Computing Machinery, 2 E. 63rd St., New York 21, N.Y.

3. Other Reference Sources

All manufacturers publish manuals describing in detail the operation of their machines. In addition some equipment manufacturers publish their own magazines describing specific applications for their own equipment.

4. Selected References

- Laubach and Thompson, "Electronic Computers: A Progress Report," *Harvard Business Review*, vol. 33, no. 2.
- Osborne, Roddy F., "GE and the Univac," *Harvard Business Review*, vol. 32, no. 4.
- Proceedings, American Institute of Radio Engineers*, October, 1953.

C. MANAGEMENT SCIENCES—OPERATIONS RESEARCH

1. Books

General—None

Technical

- Bross, Irwin D. J., *Design for Decision*, New York: The Macmillan Company, 1953.

- Cooper, Charnes, and Henderson, *Introduction to Linear Programming*, New York: John Wiley & Sons, Inc., 1953.
- Duncan, Acheson J., *Quality Control and Industrial Statistics*, Chicago: Richard D. Irwin, Inc., 1952.
- Koopmans, T. C., ed., *Activity Analysis of Production and Allocation*, Cowles Commission for Research in Economics No. 13, New York: John Wiley & Sons, Inc., 1951.
- McCloskey and Trefethen, *Operations Research for Management*, Baltimore: The Johns Hopkins Press, 1954.
- McKinsey, J. C. C., *Introduction to the Theory of Games*, New York: McGraw-Hill Book Company, Inc., 1952.
- Morse and Kimball, *Methods of Operations Research*, Cambridge: Published jointly by the Technology Press of Massachusetts Institute of Technology and John Wiley & Sons, Inc., New York, 1951.
- Shannon, Claude, *The Mathematical Theory of Communication*, Urbana: University of Illinois Press, 1949.
- Snedecor, George W., *Statistical Methods*, Ames: The Iowa State College Press, 1950.
- Von Neumann and Morgenstern, *Theory of Games and Economic Behavior*, Princeton: Princeton University Press, 1944.
- Wald, Abraham, *Statistical Decision Functions*, New York: John Wiley & Sons, Inc., 1954.
- Williams, J. D., *The Compleat Strategyst*, New York: McGraw-Hill Book Company, Inc., 1954.

2. Magazines

- American Society for Quality Control*, 70 E. 45th St., New York 17, N.Y.
- American Sociological Review*, New York University, Washington Square, New York 3, N.Y.
- Econometrica*, University of Chicago, Chicago 37, Illinois.
- Journal of Applied Psychology*, American Psychological Association, Inc., 1515 Massachusetts Ave., Washington 5, D.C.
- Journal of the American Statistical Association*, 1108 16th St. N.W., Washington 6, D.C.
- Journal of the Operations Research Society of America*, Editor, George Shortley, Johns Hopkins University, Chevy Chase 15, Md.; Membership, Norvell E. Miller, Mount Royal & Guilford, Baltimore 2, Md.
- Management Science*, Editor, West Churchman, Case Institute of Technology, Cleveland, Ohio; Business Manager, Alan Mann, SKF Industries, Front and Erie St., Philadelphia, Pa.; for subscriptions or membership in the Institute of Management Sciences, Paul Kircher, School of Business Administration, UCLA, Los Angeles 24, Calif.
- Society for Industrial and Applied Mathematics*, Box 7541, Philadelphia, Pa.

3. Selected References

- Ackoff, Russell, "Operations Research in Business and Industry," *Industrial Quality Control*, May, 1952.
- Bavelas, A., "Communication Patterns in Task-Oriented Groups," *Journal of Acoustical Society of America*, no. 22, 1950.
- Dantzig, George, "Recent Advances in Linear Programming," *Symposium on Linear Programming*, Bureau of Standards, USAF Controller, Washington, D.C., January, 1955.
- Drucker, Peter, "Management Sciences and the Manager," *Management Science*, vol. 1, no. 1., October, 1954.
- Flood, Merrill, "Management Science Today and Tomorrow. Decision Making," *Management Science*, January, 1955.
- Fortune Magazine*:
- "A Theory of Strategy," January, 1949.
- "Operations Research," April, 1951.
- "The Information Theory," December, 1953.
- "How Businessmen Make Decisions," August, 1955.
- Hurni, M. L., "Observations in Operations Research," *Operations Research Journal*, July, 1954.
- Likert, Rensis, "Developing Patterns in Management," *General Management Series, Number 178*, American Management Association, 1955.
- McGee, John F., "The Effect of Promotional Effort on Sales," *Journal of Operations Research Society of America*, February, 1953.
- Orden, Alex, "Mathematical Solutions of Programming Problems," *Management Science*, January, 1955.
- Salveson, Melvin, "Research Developments of Quantitative Method in Production," *Proceedings 5th Annual Industrial Engineering Institute, University of California*, 1953.
- Schlaifer and Henderson, "Mathematical Programming," *Harvard Business Review*, May-June, 1954.
- Simon and Holt, "The Control of Inventories and Production Rates—A Survey," *Journal of Operations Research Society of America*, August, 1954.
- Vazsonyi, Andrew, "The Use of Mathematics in Production and Inventory Control—I and II," *Management Science*, October, 1954, and July, 1955.
- Whitin, T. M., "Inventory Control Research: A Survey," *Management Science*, October, 1954.

D. AUTOMATION

1. Books

General

- Diebold, John, *Automation, The Advent of the Automatic Factory*, New York: D. Van Nostrand Company, 1952.

Wiener, Norbert, *The Human Use of Human Beings*, New York: Houghton Mifflin Company, 1950.

2. Magazines

There are a large number of technical magazines in the electronics and general production field which deal with automation. A few of special interest:

Automation, Penton Bldg., Cleveland 13, Ohio.

Control Engineering, New York, McGraw-Hill Publishing Company, Inc.

Factory Management and Maintenance, New York, McGraw-Hill Publishing Company, Inc.

Industrial Laboratories, Box 89, Village Station, New York 14, N.Y.

3. Selected References

Cf. *Control Engineering*. Bibliography published serially in various issues, 1955.

APPENDIX ONE

The Language of the Computer

This section will present a short description of the way alphabetic and numeric information, such as is printed on this page, can be translated into a code which the computer can use. There is no need for the businessman to memorize binary arithmetic, since he will never see a report in binary notation. But a knowledge of binary helps one to understand how the computers operate. Binary arithmetic has been used for machines and systems because of the ease with which it can be represented in physical terms, not because it is necessarily the best way to count.

The reader who has no interest in the internal operation of the computer can skip rapidly through this section. Those who wish to know more than is available in this brief introduction to computers should refer to the bibliography.

The sequence in a counting system can be either 001, 010, 011, 100 or 1, 2, 3, 4. Both sets of symbols "say" the same thing. The important matter is the treatment of the symbols. For this a set of rules is needed, such that the symbol "2" (or "10," in binary) shall be equal to the sum of "one" and "one."

A logical set of rules, useful for machines, was developed by a mathematician named George Boole over a century ago. His logical system emphasizes use of a minimum of these rules, primarily for the concepts "and," "or," and "not." It is usually spoken of as "Boolean algebra."

A simple system of binary counting, with decimal equivalents, appears on page 252.

Each part of the binary number is called a "bit." For example, 1010 has four bits, of which two are "ones" and two are "zeros." The value of this for electronics lies in the fact that the binary number can be

<i>Binary</i>	<i>Decimal</i>
1	1
10	2
11	3
100	4
101	5
110	6
111	7
1000	8
1001	9
1010	10
1011	11
etc.	etc.

simulated easily by electronic means. The presence or amplitude of a charge at a given time, or in a given address, may be considered as a "1"; the absence, or different amplitude, as a "0."

The problem for the design engineers was to achieve this representation of symbols in physical terms and to find ways of combining them which corresponded to the logical rules of arithmetic. The first representation of binary notation in machines was accomplished with relay switches. If a switch—like a light switch—was "off," that represented "zero"; if "on" that represented "one." A combination of two switches could represent "00," "01," "10," and "11" (with both switches off, one on, then the other on, then both on).

Addition could be accomplished by connecting the switches so that the first electric impulse turned the first switch on, the next impulse turned that one off, but in so doing sent on a pulse that turned the next one on. For example, see Figure 7.

Subsequent engineering developed faster methods of representing the data, by eliminating these mechanical movements. This was accomplished through a combination of several developments in tubes, circuits and diodes, of which a few can be illustrated rather simply. One of these was the two-stage vacuum-tube trigger circuit, usually called a "flip-flop," a combination of two tubes (or two parts of one tube) arranged so that if one tube was transmitting current, it would send part of that current to the grid in the other tube in such a way that it inhibited current flow in the other tube. Thus if one tube went "on," the other would be turned "off." The system was so arranged that when a pulse of a certain nature came in, it would turn on the tube that was off; this would send a current to inhibit the first tube

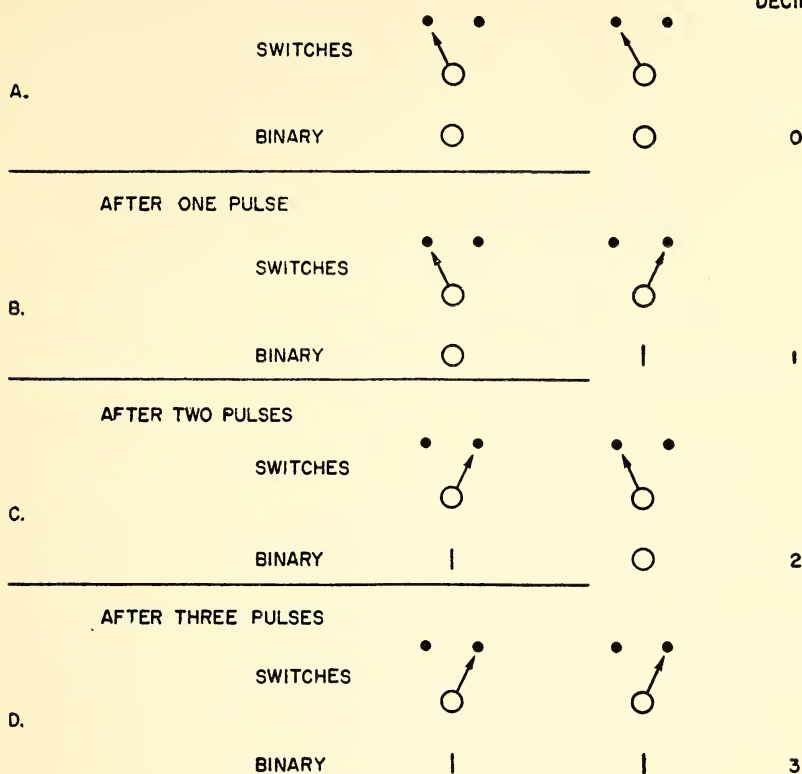


FIGURE 7

so as to turn it off. Thus there were two physical stages, both of which could not exist at the same time. If the first tube was on, the combination indicated a "0," if the second tube was on, a "1." The tube combination could represent either "0" or "1," but not both at the same time. Since this was an electronic circuit the change from "0" to "1" could be made literally in a millionth of a second.

Also needed was a method of performing arithmetical operations. This was accomplished by finding circuit and tube setups in which concepts such as the "and," "or," and "not" of Boolean algebra could be represented.

For example, if a tube could only be turned on by a current coming from both of two sources, neither of which could turn it on by itself, then there is a representation of "and" (see Figure 8). In this circuit, x , y , and z , notice that you would not want a current from x to circle

back into y , but only to go on into z . To prevent this is a function of the "diode." There are many places in a computer where the designers do not want the current to circle back. Since a diode will pass a substantial current in only one direction, putting them on both



FIGURE 8

the x and y lines prevents current from circling back. Diodes may be represented:  which means the current can go only in the direction of the arrow; in this case the current can go to the right, but not to the left.

Now suppose the designer wants a circuit that can add information simultaneously from three sources. This requires a more complicated circuit; one which uses the "and," the "or," and the "not" of Boolean algebra.

Suppose there are binary numbers "pulses" on three lines, X , Y , and Z . If A and B are first cleared and if a pulse comes in on either X , Y , or Z , then the result on the counters A and B should be "01." If there are pulses on any two of X , Y , and Z , then "10." All three should create an "11" situation, since that represents three in binary.

The circuit shown in Figure 9 will accomplish the desired result, using only "and," "or," and "not." (This diagram is of course greatly simplified. For example, there would also have to be wires to carry the "clock pulse," a timed pulse that in effect "opens the gates" at regular intervals so the other stored pulses can each advance one stage through the circuitry.)

In the diagram,

An "and" box passes a pulse only when a pulse from each of the wires is present.

An "or" box passes a pulse when a pulse from any of the entering wires is present.

A "not" box inverts a pulse. In a sense this creates a pulse if none is present.

Now if you trace the wires you will find that each of the possibilities can be handled with the proper result. For example, one pulse on

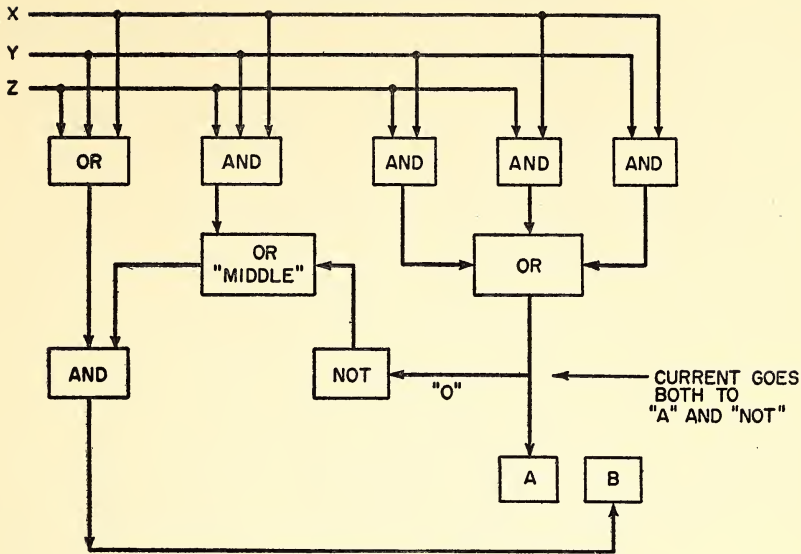


FIGURE 9

X, Y, or Z above will get through the OR on the left, be joined by a pulse from the NOT through the "middle" OR and thus turn on B, A remaining off since no pulse can pass any of the AND boxes on the right. If X and Y pulse, then A will pulse, but not B, since neither wire into the middle OR will pulse. If all three pulse, both A and B will receive pulses.

These possibilities can be shown in the following table, where a "1" below the letter indicates a current came through:

X	Y	Z	Binary Count		Decimal Equivalent
			A	B	
0	0	0	0	0	0
0	0	1	0	1	1
0	1	0	0	1	1
1	0	0	0	1	1
0	1	1	1	0	2
1	0	1	1	0	2
1	1	0	1	0	2
1	1	1	1	1	3

Multiplication can be achieved through repeated addition, and division through repeated subtraction. Subtraction in binary can be handled just as in decimal, through use of complements.

For example, an ordinary desk adder often has the "nines" complements in small print on the keys, to aid subtraction:

(72)

(36)

To subtract 32 from a number, you add 999967 + 1.

105	105
-32	99967
—	—
	72
	1
	—
73	73

In binary:

10010	10010
-101	+1111010
—	1
1101	—
	0001101
	—
11011	11011
-1001	+1110110
—	1
10010	—
	0010010

NOTE: The complement of these numbers can be obtained by reversing all positions—all the "0's" become "1's" and all the "1's" become zeros. This type of maneuver simplifies the problem of circuiting.

or

This illustration and discussion have given only an indication of the ways in which the circuits can operate. Many varieties of circuits have been suggested and tested. A "twos" complement is often used for subtraction. Some machines operate in the "parallel" fashion, in which all the parts of a number are operated on at the same time; others are "serial," in which case the number is worked on a bit at a time.

Combinations of circuits to achieve such operations as multiplication and division become quite complicated. Besides these, circuits are needed to carry the instructions, other circuits to find data in storage or to put it there, clock circuits are required so that the process will be synchronized, and so on. But while the circuitry of the machine is complex, control of the operations requires relatively simple commands to control the operations. For example, general-purpose computers can perform addition, subtraction, division, multiplication, comparison, shift, transfer, transfer if negative, and so on, as separate individual commands, each requiring only a few code numbers. The

total number of such operations varies between computers, most of the general-purpose machines having from 25 to 100 possible operations. Each operation has its own coded signal, usually in the form of a number. For example, on one machine a "14" tells the processor to divide, a "19" tells it to multiply, and an "01" tells the computer to stop.

If the sequence of the control signals is built into the computer, it becomes a special-purpose computer that can perform only the calculations for a particular type of problem.

Not only are there various systems for handling the data but there are also various methods of setting up the data to be handled. Some early computers only worked on numbers. Now computers can handle letters of the alphabet as well, coding them into binary notation just as was done with the decimal digits. Of course, this means that some binary numbers have to be reserved for letters, so the number notation cannot run as simply as the one illustrated earlier.

In addition, there are advantages to systems which only use parts of the binary numbers that are available. For example, on some machines the numbers run like this:

<i>Binary Coded Decimal</i>	<i>Straight Binary</i>	<i>Decimal</i>	<i>Binary Excess Three</i>
0000 0000	0000	0	0000 0011
0000 0001	0001	1	0000 0100
0000 0010	0010	2	0000 0101
0000 0011	0011	3	0000 0110
0000 0100	0100	4	0000 0111
0000 0101	0101	5	0000 1000
0000 0110	0110	6	0000 1001
0000 0111	0111	7	0000 1010
0000 1000	1000	8	0000 1011
0000 1001	1001	9	0000 1100
0001 0000	1010	10	0000 1101

Systems that can handle letters of the alphabet and punctuation become more complicated still. However, this does not concern the user, since business computers automatically "translate" the data from numbers and the alphabet to binary, and back again.

APPENDIX TWO

Programming

Computers operate at tremendous speeds and perform their operations automatically. But how does a computer know which operation to do next? How does it know that it should add one amount to another, and then place the total on a certain storage position, and so on?

This is the function of the "program." A program is a set of coded "instructions." Each instruction specifies the "command," or "order," which tells the machine what to do, and the "address," which tells it where to get the data on which to work, and where to put the results.

There are various types of machines. Some of them, called "multiple address," combine several addresses and a command in a single instruction. In such cases a single instruction might tell the computer where to get each of two numbers, to multiply them together, and where to put the result. Some systems only use one at a time (in which case it may require several instructions to accomplish the same result as the "multiple-address" machine accomplishes with one instruction). Each type has advantages and disadvantages.

When the instruction has been "coded" (given its symbol), it is ready for use on the machine. Different machines have different codes. For example, one computer is built to interpret "01" as a command to stop. In another computer "01" is a command to read input.

These orders and commands are given in the form of characters. Since any particular number might otherwise represent a total of items in inventory, or other quantity, this means that the person programming the machine must make certain that the logic of the machine will interpret the number as a command, not as a quantity, if that is what he wishes to do. Machines vary in logical design, so a pro-

grammer has to learn the system of the machine he is to use in order to accomplish this.

The address instruction, like the command, also is in the form of number or code. This address identifies the location of the information, just as the address of your home identifies it. When the computer is to take a number from a specific place, do something with it, and then put the number some place else, the computer must be given both a coded command and address. Part of the instruction must tell the computer where the quantity to be handled is to be found, and the other part must tell the computer what operation to perform with the quantity.

The fact that both commands and addresses are in the form of numbers is of great importance to the "programmer" of the computer. It means that he can change a command or address simply by adding or subtracting a number from it. The change can be stored in the machine. This helps enable a programmer to make the machine repeat operations, using part of a program over and over.

In many machines, the instruction is coded in the form of a so-called "word." The "word" is a number of a certain length, such as 006-042. The six digits are used in writing the program; they will form a "word" of about 24 bits when translated into binary for or by the machine. The machine is instructed to start at a certain address, say, "001," where it finds this word, "006-042." It interprets the word as a command. On the next cycle (machines usually operate in "cycles"; that is, a pulse of current is created by a clock signal at regular intervals, and an operation is or can be performed at each new clock signal), the machine will go to address "042," take the number "x" it finds at address "042," interpret the number "x" as a quantity, and perform the coded command "006" upon it. Then the machine goes on, often to the next address (002), in sequence after the address where it found the first instruction, interprets the number it finds stored in the next address as a new instruction—and so the operation continues.

To program an application such as payroll would be an impossible task if each person's pay had to have an individual program. A system is required which will enable the machines to perform a long series of operations, numbering thousands or millions of steps, by repeating those parts of the operation which are the same for each employee.

A chain of steps is attained through mathematical manipulation of the commands and addresses. The machine can repeat a series of operations, each group of operations being exactly the same as the previous one, except that one new element is introduced each time. This new element may be the payroll information about the next employee, taken from the next position on an input tape. Or, as happens in many engineering calculations, it may be the result of the previous operation. The program is designed so the last instruction in the sequence sends the computer back to the first instruction, so it goes through the same series again.

The machine can count its operations as it performs them, and can use the count to change the address being used by increasing it "one" (or any other number) after each operation. Thus the machine can be instructed to look for its first instruction in a numbered storage cell, say in the position in storage given the "address"—2011. After completing the instruction found there, the machine can add "1" to the "2011," obtaining "2012." It will then go to storage location "2012" for its next instruction. This may continue until it reaches "3000," at which point the instruction in "3000" may be, go back to "2011" again, so the cycle repeats.

In the meantime, the instructions have caused the machine to read the next item on the input tape. This means that the whole cycle of instructions stored in addresses from 2011 to 3000 will be repeated again, using one different input item. Obviously this process, called a "loop," can be repeated as many times as desirable.

The machine can count the number of times the loop is repeated, and turn to some other routine after the count reaches a predetermined total. Suppose you wish a machine to repeat a calculation 20 times. If you put a "19" in the storage, and ask the machine to subtract the count of the number of times it has performed the calculation from 19, and to do this after each calculation, then after the twentieth repetition the difference between the two amounts will be negative for the first time. The computer can be instructed to start on something else at this point by a "transfer if negative" command.

An example of such a program, with explanations, for a machine that has a "three-address" system is shown in the following illustration:

Suppose the machine reads an instruction composed of a "command" (first column, below) and three different addresses (next three

columns). In the illustration letters are used to show commands for easier study; actually, the command also would be given to the machine in the form of a binary number. For example, instead of Mu. 001 101 104, the first instruction would be of the form 06 001 101 104. The machine is built so that the electrical impulses symbolizing "06" cause multiplication to take place between the figures stored in storage location 001 and storage location 101. The result is stored in 104.

The first step is to punch cards or prepare tape to show, say, the balance of 100 bank accounts. Then the cards or tape are read into the machine. The computer can place each separate balance in a separate storage, addressed from 1 to 100 in the illustrated program.

Then cards or tape must be punched for the numbers which convey the instructions. The set of these instructions is the "program." These cards or tape are then read into the machine, which is set to store constants in storage locations 101 through 105, and instructions in 110 through 114. (NOTE: 104 is left blank as an operating space.)

Now the computer is ready. An operator signals it to start. It goes to storage location 110. When the machine reads the contents of 110, it finds it is to multiply the contents of 001 by the contents of 101 and put the result in 104. Then, since this was a "multiply" command, the machine automatically goes to location "111" (1 more than "110") for its next command (see explanation column), then to "112," then to "113." When it reaches "114," however, it finds a "compare" command. This instruction is interpreted in a special way, which can call for either of two possible next instructions:

a. If the number stored in "105" (Mu. 101 101 104) is larger than the number stored in "110," go back to "110" and repeat the cycle. Note, the number in "110" started at Mu. 001 101 104 but it has had the number in "102" [+ 001 000 000] added to it each cycle, so the amount in "110" gradually nears and finally reaches equality with the figure in "105." The number in 111 also is changed each time, so a new bank account is worked on each time, or:

b. If "105" is not greater than "110," go to 115 ($114 + 1$).

NOTE: Storing new information erases old; merely reading does not erase.

A general-purpose computer is flexible and can be instructed to perform many types of routines. It can be instructed, through the inserted program, as to which routine it is to do next. Given the

PROGRAM

<i>Computer Storage Address</i>	<i>Command</i>	<i>First Address</i>	<i>Second Address</i>	<i>Third Address</i>	<i>Explanation</i>	
001	+	000	721	4.93	Account 1	\$7,214.93
002	+	000	003	5.08	Account 2	35.08
.						
099	+	000	016	442	Account 99	164.42
100	+	000	001	234	Account 100	12.34
101		050	000	000	Rate 5 per cent.	
102		001	000	000	Number used to modify contents of Address 110.	
103		000	001	001	Number used to modify contents of Address 111.	
104					Spare register for interest.	
105	Mu.	101	101	104	Special constant to control loop.	
Start						
110	Mu.	001	101	104	Multiply account No. 1 in address "001" by rate in 101 and store interest in 104. Later, use address "002," etc.	
111	Add	104	001	001	Add interest in 104 to old amount in 001 and store back in No. 001.	
112	Add	110	102	110	Add contents of Address 110 to Address 102 and put result in Address 110. This changes the address of the account worked on each time.	
113	Add	111	103	111	Add contents of Address 111 to 103 and put result in Address 111. This changes the addresses worked on by "111."	
114	Compare	105	110	110	If (105) is greater than (110), go to 110 and recirculate once again. Note that 110 and 111 now operate on the next account because the number of the address to which they refer has been increased by 1. The special constant in 105 is the final configuration which instruction in Address 110 will assume for this problem.	
115	Finish				After the last item is compounded the constant will no longer be greater than the contents of Address 110, and the next instruction will be taken in order from Address 115, which here tells the machine to stop. It might tell it to start another routine.	

steps of the routine, it will follow them faithfully. As part of the program, it can automatically stop this routine and start another when it reaches the end of an input tape, or reaches a certain mathematical result, and so on.

Large-scale computers gain their versatility because they can perform a number of very simple operations, perform them in any desired order and very rapidly. They can be instructed to take a figure from one place and to put it in another place, unchanged. In doing so they may or may not erase the original record, as desired. They can change the number by adding it to another, taken from any specified address in the system, then place the result in any desired address, either in the arithmetic unit where it can be processed further, or in one of the storage locations.

Computers can compare numbers, and place the larger or smaller in specified locations, and so on. These are only examples. Through proper combination of the various abilities, a "programmer" can set forth a series of instructions which will result in any desired performance. There are so many of these possibilities that he can make the electronic machine perform simple accounting routines, as well as high-powered mathematical routines.

As another approach, visualize a computer program something like this: Suppose you have an accounting procedure which is handled by a roomful of clerks. You want to go on a vacation. The clerks can only follow instructions. If you want to avoid a stoppage while you are away, you must write out exactly what they are to do in any eventuality—that is, a line-by-line description of each type of report they are to receive, what they are to do with the information (add which figure to which, etc.), and where they are to file or report the results.

If you wrote out all the steps for each possible document and for each bit of information, then you would have a program.

The analogy can be carried a bit further. Before going on the vacation, you should leave the office for a few hours to see whether the clerks can operate from the instructions—which is equivalent to testing a program on the computer before you start to run your regular data through it.

Moreover, if you ever go on vacation again, you may be able to use the same set of instructions, with a few changes here and there to bring it up to date. Similarly, you can build up a library of stored

programs, so that the effort required to set up a program need not be completely duplicated for similar problems in future.

You can build up a library of "subroutines"—pertinent parts of a routine—so that a future program may consist largely of making choices from a group of these subroutines, each of which has previously been used and therefore tested. This will cut down considerably on the time it takes to program a new set of operations on the computer.

There is no single way that the various abilities of the machine must be combined in order to make a routine. A skillful programmer can make up a shorter series of steps and this saves considerable operating time on the computer. He can also program better checks against errors of various kinds in the information.

APPENDIX THREE

Electronic Data-processing Equipment

This appendix presents specific details concerning electronic equipment. Most of the equipment described is commercially available or exists at scientific installations. In a few cases of special interest, equipment in the laboratory stage will be mentioned to show the variety of possible designs; for the most part these will be special components.

In no sense is this a catalogue. The purpose is solely to give a picture of the characteristics of typical machines. The material is not complete in that some machines will not be described. Moreover, since the field is developing rapidly, certain details change. For current information it is necessary to contact the manufacturer.

In order to make the material somewhat more understandable, certain arbitrary groupings have been made. For example, the BIZMAC, IBM 705, RAYCOM, and UNIVAC are discussed together as representative of large-scale general-purpose systems. The speeds, type of components, and storages are somewhat similar. However, there are major differences, particularly in the logical instructions. These are not easy to present in summary fashion, yet they combine to make each machine quite distinct. As indicated in the text, a number of potential customers have full-scale research projects which are attempting to assess the suitability of each of these machines for particular applications.

PART A—LARGE-SCALE GENERAL-PURPOSE SYSTEMS

Section One—Business Computers. As indicated, there are four large-scale general-purpose computers in this country offered for

commercial use. (Ferranti of England may have a machine in this field, otherwise, foreign computers are usually smaller in scale.) Of the four, UNIVAC and the IBM 702-705 series have been in full-scale production for some time. The RCA BIZMAC was not offered until 1955 for 1956 delivery, but a model had been built. The Raytheon-designed RAYCOM is the latest entry, and for a while should be considered as somewhat less proved in performance. The BIZMAC and RAYCOM were not in commercial production at the time this appendix was written.

All are in the million-dollar class. Rentals vary from \$20,000 to \$50,000 a month, depending upon the number of auxiliary units.

The IBM 705 is an improved version of the 702. The UNIVAC also has been redesigned, and the new model is called UNIVAC II. In both machines a major change was the replacement of prior high-speed memory with the new magnetic-core type, which increased speed and reliability.

<i>Machine</i>		<i>Manufacturer</i>			
IBM 705		International Business Machines			
UNIVAC II		Sperry Rand			
BIZMAC		Radio Corporation of America			
RAYCOM		Datamatic			

<i>Input-Output</i>	<i>IBM 705</i>	<i>UNIVAC II</i>	<i>BIZMAC</i>	<i>RAYCOM</i>
Magnetic tape				
Speed, characters per second.....	15,000	20,000	10,000	37,000
Number of tape units possible.....	By using buffers, virtually unlimited.			
Tape reels, capacity.....	Varies; top length about 2,400 feet; recording density, 125-200 characters per inch; one reel holds several million characters; it takes several minutes to run from one end to the other.			

All four systems will handle punched cards. The IBM 705 starts with punched cards, which it reads directly or can convert to tape. It has a typewriter which prepares punched cards simultaneously with typed copy. The UNIVAC has card-to-tape converters, but also has tape-preparation typewriters. The BIZMAC also has converters, and in addition will handle both five- and seven-column punched-paper tape. Machines typically read one tape and write on another, but some can read and write on the same tape.

	IBM 705	UNIVAC II	BIZMAC
Printers			
Full 100-130 characters, lines—per minute	500 or 1000	600	600

BIZMAC offers an electronic photoprinter which reads magnetic tape and produces 2,000 characters a second—approximately equal to a 120-character-per-line, 1,000-line-a-minute printer. All systems can be used with punched-card printers, via the converters.

	Operations per Second		
Arithmetic	IBM 705	UNIVAC II	BIZMAC
Add	8,400	5,000	2,000
Multiply	1,250	1,000	200
Divide	212	500	50

These speeds are only approximate, and have been rounded for convenience. A five-digit number was taken as standard. Some machines take longer for larger numbers, others do not (up to a point). The UNIVAC, for example, has the same speed as shown above for a ten-digit number, while the 705 is slower. "Add" and "subtract" are the most rapid commands; "divide" the slowest. RAYCOM speeds are comparable.

Storage. All use magnetic cores for high-speed random access, at about ten to twenty millionths of a second. Storage capacity for each is about 20,000 characters, except for the BIZMAC (4,000). The machines can add several core storage units, but the extra memory is expensive and probably not economical for most business applications.

The IBM 705 and the BIZMAC have magnetic-drum memories for medium-speed random access. Capacities are 60,000 characters per drum, up to 30 drums, for the 705. Capacity of the BIZMAC drum is 30,000 characters.

The main storage in all systems is on magnetic tape. Tape characteristics were described in the section on input-output.

Logic. The logic of the systems varies considerably. Basically, each of them can perform any arithmetic or comparison requirement and can copy and compare alphabetical information. However, these operations are performed by combining a number of instructions, which vary from machine to machine. As a result, flexibility and speed differ for different requirements. A machine which appeared faster, in the table given previously, might not be able to do a complete opera-

tion from input to output as fast as another, because of peculiar requirements of a business problem.

It is not feasible to discuss all the aspects of logical design, such as the fixed word length of the UNIVAC versus the variable word length of the IBM 705.

To give an indication of the type of instructions required, those for one machine will be given—for the IBM 705:

<i>Arithmetic</i>	<i>Programmers' Abbreviation</i>	<i>Machine Code</i>
Add from memory to the accumulator, where arithmetic takes place	ADD	G
Add from accumulator to memory (core storage)	ADM	6
Set accumulator to zero, then add from memory	RAD	H
Subtract from memory to accumulator	SUB	P
Set accumulator to zero, then subtract from memory	RSU	Q
Multiply	MPY	V
Divide	DIV	W

The programmer defines the problem and determines a suitable machine procedure for solving it. The coder writes out the instructions that solve that problem; for example, RAD 0601, etc. The key punch operator, or typewriter operator, prepares the input. The machine can translate the "RAD 0601" to the "H 0601" which it actually uses in internal processing. It does this by means of a special program. In this way it aids in making its own programming easier. When the machine reaches this point in the program, it will go to core memory location 0601 and place the contents of that location—which may be a letter, a single number, or a symbolic mark such as a #—in the central processing unit called the "accumulator." The letter, mark, or symbol will then be available in the accumulator, for though the item was "added," the accumulator was erased of previous contents before it arrived. The number is then available to be added to, or multiplied by, another number, etc., or perhaps merely relocated in another portion of the high-speed core memory or on the magnetic drum.

There are over forty such symbol or number commands for the 705, not including variations that deal with the sixteen different accumulators, which are individually addressable. Those instructions not shown deal with such commands as selecting the input or output

tape, card reader, card punch, or printer; also reading, writing, lengthening (roughly equivalent to adding zeros at end of word or number) shortening, rounding (differs from shortening in that "5" is first added to the position to be dropped), rewind tapes, back-space, compare, transfer if high, transfer if equal, unconditional transfer (note, "transfer if low" is omitted, but the same result can be achieved by programming "transfer if high," then "transfer if equal," then "unconditional transfer"), etc.

Section Two—Scientific Digital Computers. There are a large number of computers of different designs but similar in that they are primarily suitable for high-speed scientific computations. Usually input and output are more limited than for the commercial computers. Speeds are, in general, as fast or even faster. The NORC, built by IBM for the Navy, is about eight times as fast as speeds listed above; it can make over 30,000 calculations a second. The LARC, designed by Sperry Rand, is even faster.

Since many of these computers are available for commercial work on a rental, part-time basis, and since most are used by universities or scientific groups that hold classes or occasionally welcome visitors, a partial listing may be of interest.

The division is geographical, with commercial builders shown at their headquarters for production, in most cases.

United States

California

Bendix Aviation, Los Angeles.

Electro-Data (formerly part of Consolidated Engineering), Pasadena.

SWAC and BINAC, University of California, Los Angeles.

Johnniac, RAND Corporation, Santa Monica.

J. B. Rea, Los Angeles.

Litton Industries, Beverly Hills.

Ramo-Wooldridge Corporation, Los Angeles.

North American Aviation Corporation, Los Angeles.

Librascope, Inc., Glendale.

LARC (in design), University of California, Larchmont.

District of Columbia

SEAC, DYSEAC, Bureau of Standards.

NAREC, Naval Research.

Logistics Computer, George Washington University.

Illinois

AVIDAC and ORACLE, Argonne National Laboratory.
ILLIAC, University of Illinois.

Maryland

ORDVAC, Army, Aberdeen.

Massachusetts

MARK series, Harvard.
Whirlwind series, M.I.T.
RAYDAC, Raytheon, Waltham.

Michigan

MIDAC, University of Michigan.
Wayne Computer, Detroit.

Minnesota

ERA series, Sperry Rand, St. Paul (also called UNIVAC Scientific).

New Jersey

Bell Computer series, Murray Hill.
Institute for Advanced Study, Princeton.

New York

IBM 701, 704
Remington Rand UNIVAC Division of Sperry Rand.

Pennsylvania

Burroughs, Philadelphia.
Sperry Rand, Philadelphia.

Virginia

NORC, Dahlgren (IBM).

Wisconsin

WISC, University of Wisconsin.

*Foreign Countries**Australia*

C.S.I.R.O. Mark I Commonwealth and Industrial Research Organization.

Belgium

IRSIA-FNRS Computer, Bell Telephone of Antwerp.

Canada

UTEC, University of Toronto.

England

ACE National Physical Laboratory, Teddington.
APE(R)C, APE(X)C, APE(X)C, University of London.

Harwell Computer, Atomic Energy Research, Harwell.

EDSAC, Cambridge University.

LEO, a commercial computer, built by the restaurant chain, J. Lyons & Co.

Elliott-NRDC, Elliott Brothers, London.

Manchester Computer, Ferranti Ltd., for University of Manchester.

TRE Computer, Telecommunications Research, Great Malvern.

France

GAMMA, Compagnie des Machines, BULL, Paris.

CUBA, Laboratoire Central de L'Armement, Paris.

Germany

PERM, Technische Hochschule, Munich.

G 1, G 2, Max Planck Institut, Göttingen.

MARK IV (similar to Harvard design), Technische Hochschule, Darmstadt. Also Rechenautomat IPM.

Z 4, Z 5, Zuse K. G. Neukirchen (one installed in Switzerland).

Japan

TAC, University of Toyko.

Tokyo MARK I, II, Electrotechnical Laboratory, Tokyo.

Netherlands

ARRA, Mathematische Centrum, Amsterdam.

PTERA, Central Laboratory, Postal and Telecommunications, The Hague.

Sweden

BARK, BESK, Kunglig Tekniska Hogskola, Stockholm.

Switzerland

R4S, Technische Hochschule, Zurich.

USSR

No precise data available, but analysis of budget reports and technical articles indicates that a large number of computers of advanced design are in operation.

PART B—MEDIUM-SIZE GENERAL-PURPOSE SYSTEMS

There are a number of medium-size systems in commercial production. The position of this equipment is not easy to assess—in some ways it is even more difficult to evaluate than that of the larger systems. Most of the machines are adaptations of designs that were originated for scientific purposes. Because the systems are more limited in scope than those described in the previous section, it has

been found more difficult to tie them to existing data-processing systems than was hoped at first. However, considerable effort is being expended to increase the commercial effectiveness of this type of equipment. For example, the IBM 650 originally could only use punched cards as input-output. Now it has magnetic tape. Other machines only had tape; they are being fitted with card-to-tape converters.

Generally speaking, the medium-size machine can be distinguished from the larger equipment by the fact that it uses a magnetic drum for high-speed random-access memory. This makes the arithmetic and logical operating time roughly ten times that of the high-speed machines. However, limitations exist at other points, such as at input and output, so that in many cases the over-all time for processing information may be twenty times or even fifty times that of the larger equipment.

The following machines may be considered in this category although they differ considerably in certain aspects of their operations (as will be noted in some cases):

<i>Machine</i>	<i>Manufacturer</i>
UNIVAC File Computer	Sperry Rand
IBM 650	International Business Machines
Datatron	Electro-Data
Miniac	Marchant Calculators
Monrobot	Monroe Calculating Machine
CRC and NCR series	National Cash Register
Elecom series	Underwood
Magnefile	Electronics
Circle	Hogan
E 101	Burroughs
LGP 30	Librascope
Alwac	Logistics Research

Other manufacturers interested in this type of machine include Telecomputing, International Telemeter, Litton Industries, and Magnavox.

Prices for these machines vary from several hundred thousand dollars (or about \$6,000 to \$10,000 a month rental), for those at the top of the list (including auxiliary equipment), down to about \$50,000 for those toward the end. All the larger systems have magnetic-tape units; some of the smaller ones use punched-paper tape, cards, or Flexowriters and keyboards. If magnetic tape is not used, the over-

all processing time increases to as much as one hundred times that of large systems, or even more.

A major attribute of the UNIVAC File Computer is the ability to link as many as 24 input-output units, and as many as 10 magnetic drums, to the central processor. From this the machine derives its name, since it can reach any one of several hundred thousand short records in a fraction of a second.

The IBM 650 originally had card input-output, at which stage it was usually considered to be primarily useful for scientific or semiscientific calculations. Redesign added capacity to handle six tape units. Over a thousand of this model have been installed or are on order.

The Datatron has the ability to handle punched-paper tape in addition to magnetic tape and punched cards. It is somewhat larger and faster in operation than most of the others classed as medium-size. The manufacturer uses IBM card readers, punches, and printers.

The Miniac features input typewriters that prepare magnetic-tape "magazines," which are somewhat comparable to the cartridges used to transport movie film in some types of cameras. These magazines can be mounted and demounted rapidly on the computer. It also can handle paper tape.

The Monrobot design features flexibility of input-output components--teletype, Flexowriter, punched card, paper tape, magnetic tape.

NCR equipment (formerly Computer Research) emphasizes point-of-sale recording.

Elecom has an unusually efficient sorter. This ability is lacking in most systems; although the machines can sort, the process is comparatively slow.

Magnefile is a smaller machine with a comparatively large drum memory. It has been used primarily to record sales data where immediate totals are desirable. It can be obtained with keyboard input.

The other machines also have varying characteristics, which will not be detailed here, since the intent is only to provide some indication of the variety obtainable.

PART C--SPECIAL COMPONENTS AND OTHER EQUIPMENT

When one leaves the field of developed systems and begins to examine the variety of special components and devices, it becomes difficult to give useful summaries. There are literally hundreds of manu-

facturers who are interested in this rapidly expanding new industry. In addition, the major manufacturers have active research programs which are developing devices which they intend to link to their systems.

An example is the IBM 305. A series of discs is mounted in a manner similar to records in a juke box. A moving head can reach the surface of any part of any disc in less than a second. This gives the device rapid access to millions of characters. (The discs are similar in function to a magnetic drum.) Sperry Rand and others have designed similar disc memories.

Another is the print reader. Intelligent Machines, Burroughs, IBM, and others have developed print-reading devices which work in limited applications. A major effort is under way to improve them.

A different item is the special-purpose system. An example is Tele-register's American Airlines Reservisor. There are many others, ranging from utility power-grid simulators and digital differential analyzers such as the Litton-20 to equipment which verges on other fields such as telemetering.

A number of companies have special components, such as Potter, (tape readers, storage units), Convair (photographic printer), (Standard Register (devices to code paper document with metallic spots, and convert to punched cards, as well as an electronic "smoke printer"), Burroughs (high-speed printer), etc.

No mention has been made of devices which are used for automation of production. Large-scale systems are not yet available in this field, i.e., systems suitable for a variety of industries. Instead, each application uses a number of different components, assembled for the particular application.

A few devices, primarily those for assembling small electrical parts, have found several applications. An example is the equipment developed by General Mills and United Shoe Machinery.

It is impossible even to list all the manufacturers and types of devices available. Perhaps it will serve to indicate the scope of the field by mentioning that electronic data-processing devices and automatic controls are a several-billion-dollar industry already—all developed since World War II—and that forecasts indicate it should double in size within a few more years.

APPENDIX FOUR

*A Mathematical Model for Integrated Data Systems **

Chapters 4 and 5 discussed the background of the data-processing-system problem. Chapter 9 indicated some of the types of research that are being and can be done at present. Of the "models" referred to in these earlier pages, some relate only to parts of the system—to applications which can be made today. This section describes such a model in more detail.

A mathematical model of an integrated data system would be based on an analysis of the following major elements:

1. The events to which the source data refer.
2. The data flow, from the origination of the record, through transmittal and processing, to the end stations where the data are used. This would include the informal communication system as well as the formal flow. The form of flow would be primarily that of "combining" as described in Chapter 9.
3. The use of the data in programming, scheduling, and feedback. The form of flow would be primarily that of "branching."

Research groups are working on various aspects of the problem. The theory of communication developed by Wiener and Shannon is being applied in studies of various information systems, studies which include a fairly complete analysis of the organizations involved. The statistical decision functions developed by Neymann and Wald, and the theory of games of Von Neumann and Morgenstern, represent still other approaches. Mathematical programming techniques developed

* The authors are indebted to Irving Lieberman of Litton Industries for his aid in the development of the mathematical models in this appendix.

by Koopmans, Dantzig, and Marschak, the psychological studies of Bavelis, as well as the input-output approach of Leontieff, are further examples of the scientific work which is being done. All these efforts are in fields which have direct bearing on the business data processing and the business decision problems which must be solved if we are to achieve integrated business systems.

Although as yet a truly integrated model cannot be achieved, mathematical models can be developed which describe the part of the system concerned with the basic flow of data. Such models can symbolize the source points of data origination, the form of information transmitted, the channels through which the information flows, and the activities which receive the reports. The models can be studied to determine quickly who originates data, the volumes of flow, the extent to which the flows and storages are duplicated, and so on. The models also can be used to show the timeliness of the various levels of reports. A change in various parts of the system can be traced easily to determine the effects the change will have on the over-all system.

By using the models particular problems can be studied, such as determining if a feedback system is correctly related to the schedule, so that comparable variance data are provided.

However, while such a limited model may symbolize data flows and reports, it cannot measure the effectiveness of the decisions made by the end users of the data. If these could be measured and related directly to the data-processing system, they could be incorporated into the model, in part at least. In other words, the models being developed for programming, scheduling, and feedback then could be integrated with the data-processing model.

The remainder of this appendix gives a description of the way a mathematical model can be constructed for an existing system of gathering and processing data. It is a descriptive model. The purpose of constructing such a model is to enable a business to:

1. Simplify the manner of gathering and processing data.
2. Determine the results of changes in the system before actual changes are made.
3. Reduce costs by eliminating duplications.
4. Speed up the reporting.

5. Establish a sound basis for selection of equipment for business systems.

The first step is to define explicitly the terms which will be used in the mathematical model. These terms are used to describe the typical operations in the system, such as the recording of the data on source documents, transmittal and reproduction on intermediate reports, processing to summary reports, and delivery to persons in particular business functions. Symbols are assigned to each term.

The following terms and symbols will be used:

1. *Business functions*—"W"—those activities which are grouped according to similar kinds of duties, such as production control, cost accounting, sales, and so on. The mathematical analyst usually can start with the definition of the functions as he finds them in a specific company, though some clarifications will probably be necessary.
2. *Information documents*—"F"—the forms on which data are recorded. *F* is subdivided into two major classes:
 - a. *Source forms*—"F_s"—documents on which information is recorded for the first time. The information is not obtainable by an operation from any other form, either by copying or by some computation.
 - b. *Report forms*—"F_R"—documents for which the information is obtained by performing an operation or a combination of operations on data from *F_s*.
3. *The information itself is designated as "C."* Two classes of information are generally found:
 - a. *Identifications*—"i"—information which describes or identifies. Examples are the date, invoice number, payroll number, description of material, department number, and so on.
 - b. *Quantities*—"q"—information which gives a quantitative measure, which shows amounts. Examples are hours worked, number of pieces produced, value of items transferred, costs, revenues, ages, and so on.
4. *The time ordering*—"t"—of information is important. This refers to the relative time that information arises, or is made into a report, not the specific date this occurs. A series of times can be represented: t_1, t_2, t_3, t_4 .

5. *The informal communication channels—"I."* This symbol designates the transfer of items by means other than documents.

Using these symbols, the mathematical model can be made to reflect the relationships between the classes of information, the forms on which they appear, and the time order of these forms. Steps in the development of the model will be as follows:

1. Determination of the source data forms F_s and the information collected on each form, the i 's and the q 's. To distinguish each source form, numbers will be added, F_{s1} , F_{s2} , and so on. The i 's and the q 's also can be numbered, i_1 , i_2 , and so on; q_1 , q_2 , and so on. If the same i appears on two different forms, it will be given the same number, since this is one of the ways that duplications can be uncovered. The time order of the source form can also be shown— F_{s1}^1 .
2. Determination of the report forms, F_R , showing the sequence of data flow from the F_s , or from other F_R . The sequence can be numbered as to different types of forms, F_{R1} , F_{R2} , etc., and as to different occurrences of the same type, $F_{R1,1}$, $F_{R1,2}$, etc. The time of each can be noted— $F_{R1,1}^1$, $F_{R2,1}^2$, and so on. Time has been omitted from the models below for simplicity of presentation.
3. Determination of the reports received by each organization (W). The various organizations can be numbered— W_1 , W_2 , and so on. If it is necessary to distinguish the various hierarchical levels in the organization, another number can be added to indicate this— $W_{1,2}$, $W_{1,3}$, and so on.
4. Determination of the role of the informal communication system, showing the types of i 's and q 's which are transmitted thereby, together with the time order of the transfers.

The model will take the form of a matrix, since this is a simple way to show the relationships between two groups of relevant items.

	F_{s1}	F_{s2}
i_1	0	1
i_2	1	1

This shows that information i_1 appears on form F_{s2} , and i_2 appears on both F_{s1} and F_{s2} .

It is now possible to build a mathematical model of an integrated business-data system using the above notations. The data collected within a given company can be recorded in a matrix which discloses, first, the source forms, and the classes of information gathered by a source form. This source-data-form matrix will be given the notation of M_0 .

M_0

	F_{s1}	F_{s2}	F_{s3}	$\dots$	F_{sm}	Last F_s
First $i = i_1$	1	0	1		1	
• i_2	0	0	1		0	
• i_3	1	1	1		1	
• •						
• •						
• •						
Last $i = i_u$	0	0	1		1	
First $q = q_1$	1	1	1		1	
• q_2	1	0	0		0	
• q_3	1	0	0		0	
• •						
• •						
• •						
Last $q = q_y$	0	0	0		0	

All of the i 's and q 's must be determined. They must then be examined in relation to the source-data forms. Either an item appears on a form, or it does not. This can be represented by "0" if the item does not appear, and by "1" if it does. The matrix, therefore, will show only "0's" and "1's."

After the M_0 matrix has been completed, the next step is to construct a matrix showing the relationship between the F_s forms and the first level of report forms, F_{R1} . This matrix is designated M_1 .

M_1

	F_{R11}	F_{R12}	F_{R13}	$\dots$	F_{R1p}
F_{s1}	1	1	0		0
F_{s2}	1	0	0		0
F_{s3}	0	0	1		1
$\cdot$					
$\cdot$					
$\cdot$					
F_{sm}	0	1	0		1

The matrix is filled out in the same way as the previous one. If any information from an F_s is used on an F_R , then a "1" appears, if none, a "0." Note that the "1" shows the information is available and that some of it is used, but not that all the information items from the particular F_s appear on the F_R .

A matrix for second-level-report forms, showing their relationship to first-level forms, is designated M_2 . It appears:

 M_2

	F_{R21}	F_{R22}	F_{R23}	$\dots$	F_{R2r}
F_{R11}	1	0	0		0
F_{R12}	1	1	1		1
F_{R13}	1	0	0		0
$\cdot$					
$\cdot$					
$\cdot$					
F_{R1p}	0	0	1		1

A similar use of "0" and "1" is made to show that some information is taken from one form for use on another.

Matrices for subsequent levels will continue with the same pattern.

M_3

	F_{R31}	F_{R32}	F_{R33}	$\dots$	F_{R3w}
F_{R21}	1	0	0		0
F_{R22}	0	1	0		1
F_{R23}	1	1	0		1
$\vdots$					
F_{R2r}	0	0	0		1

The next level is designated M_3 .

The order of time is greater for the report forms on each higher level, in each higher-level matrix. This is necessary, since the system predicates that the reports on the higher levels are using data taken from those on lower levels, and thus must succeed them in time.

If new source data appear on a report from one that was previously made up from other sources, then the form should bear a report designation showing the appropriate report level, not as starting back on the M_0 level. In other words, a form may be mixed in that it may contain both report and source data. But the ordering requires that the report level be established by the level attained as a result of the largest number of steps or prior processing for any of the information shown on the form.

Study has shown that report-form levels will usually tend to parallel a company's organizational levels. Since there are about three to five levels in many typical organizations, this sets the number of matrices which will be required to reflect this part of the system. Another matrix is required to show the functions using the reports. If this last matrix can be produced at the level at which we have just concluded our illustrations, the matrix can be designated M_4 , and will appear as follows, where W indicates functions:

M_4

	W_1	W_2	W_3	$\dots$	W_z
F_{R31}	1	0	1		1
F_{R32}	1	0	0		0
F_{R33}	0	1	1		0
.					
.					
.					
F_{R3w}	0	0	0		1

Analysis of the Model. An example of the use of the model can now be given. Consider any row across any matrix. "0" and "1" will appear in various boxes. Each time that a "1" appears this indicates a use of the information. Therefore the summation of the row (addition of all the i 's that appear) gives an indication of the extent to which that item is used. If the sum is "0," the information is not used; it is redundant.

Next, consider the columns. These show the number of items that appear on a particular report (or, in the last matrix, are used by a particular function). The sum of the column, therefore, indicates the amount of information used on that report or available to that function.

The rows and columns of matrix M_0 can be summarized as follows:

Rows	Sum	Columns	Sum	Sum of the i 's	Sum of the q 's
i_1	3	F_{s1}	5	2	3
i_2	1	F_{s2}	2	1	1
i_3	4	F_{s3}	5	4	1
.		.			
.		.			
.		.			
i_u	2	F_{sm}	4	3	1
q_1	4				
q_2	1				
q_3	1				
.					
.					
.					
q_v	0				

From the summary it can be seen, for example, that information item q_v is not being collected, although apparently it was listed as one of the regular information items during the initial study. Other rows show incidence as high as four times, which indicates the level of use of the particular items.

One of the valuable attributes of matrix mathematics is that the matrices can be "multiplied" together. In effect, this means that the lower-level matrix can be "merged" with the upper, so as to show the items of information which are combined for one report, and then combined again for the higher-level report.

Multiplication of items on M_1 and M_2 gives the following results, designated M_{R1} :

$$M_0 \times M_1 = M_{R1}$$

	F_{r11}	F_{r12}	F_{r13}	F_{r1p}
i_1	1	2	1	2
i_2	0	0	1	1
i_3	2	2	1	2
.				
.				
.				
i_u	0	1	1	2
q_1	2	2	1	2
q_2	1	1	0	0
q_3	1	1	0	0
.				
.				
.				
q_v	0	0	0	0

The process can be repeated, multiplying M_2 by M_3 , for M_{R2} and M_3 by M_4 for M_{R3} . The result of multiplying the whole series $M_0 \times M_1 \times M_2 \times M_3$ is designated as M_R .

If, in either M_{R1} , M_{R2} , M_{R3} , or M_R , the number in any "box" is greater than one, this shows that the information is being repeated and theo-

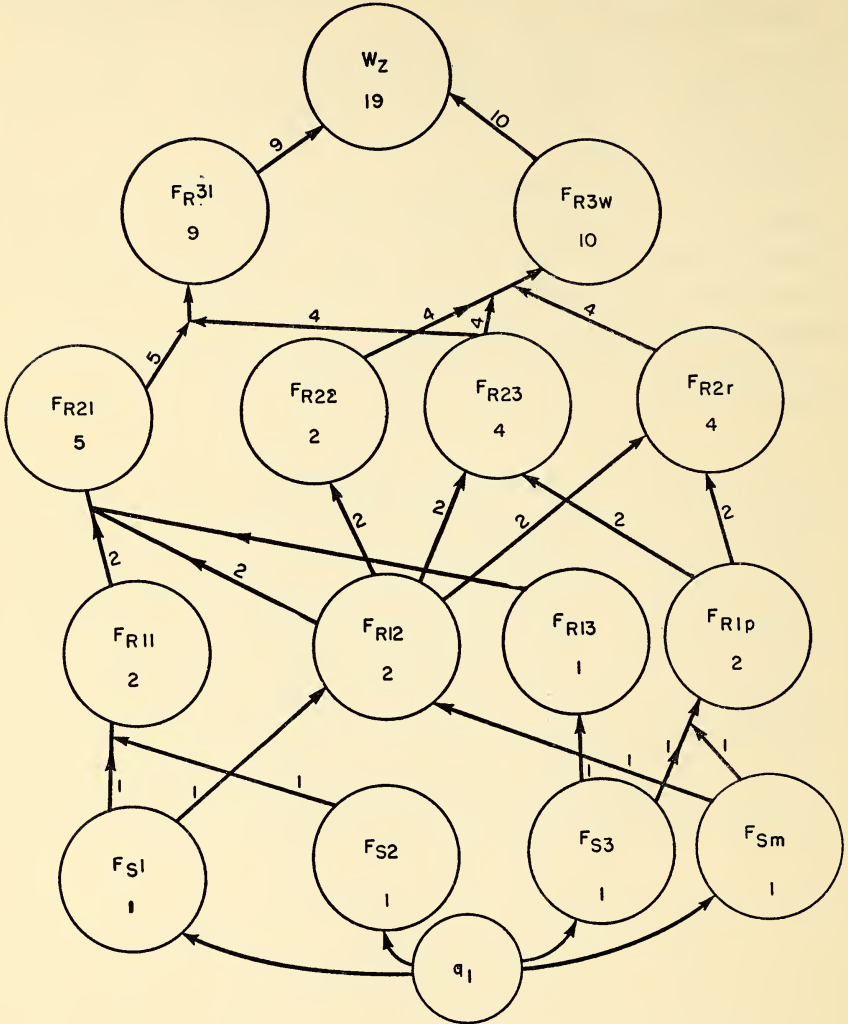


FIGURE 10

retically is redundant. A measure of the redundancy is given. Another way of stating this redundancy is to say that the same i 's or q 's appear on more than one source form, or that a source form appears on more than one report form, or a combination of both.

For example, in a complete matrix M_R , it may be shown that information item q_1 may be available to function W_z as many as 19 times. Figure 10 shows how this may occur. For the nonmathematical reader

this is shown in flow-chart form rather than in matrix arithmetic. Both methods show exactly the same thing.

Figure 10 on page 284 shows that every F_s collected q_1 ; the information was to a large extent redundant for function W_z , as well as for first-level reports F_{R11} , F_{R12} , and F_{R1p} ; for second-level reports F_{R21} , F_{R23} , and F_{R2r} ; and for third-level reports, F_{R31} and F_{R3w} .

The model given is for the formal part of the communication network. As indicated earlier, the informal net often plays a major role in determining the effectiveness of the system. For this reason it is desirable to make up a model of the informal contacts and communications, in so far as these can be obtained.

A simple indication of such informal links can be given in matrix I which shows only that certain functions communicate with others on a fairly frequent basis:

I

	W_1	W_2	W_3	$\dots$	W_m
W_1	0	1	0		1
W_2	1	0	0		0
W_3	0	0	0		1
$\cdot$					
$\cdot$					
$\cdot$					
W_M	1	0	1		0

In the matrix I , "0" indicates no communication of value, and "1" indicates informal communication of some value.

A more refined version can be developed to show the types of information thus transmitted, the i 's and the q 's which flow along these informal channels. In addition, the time order of the information can be denoted, with the usual t 's and their subscripts. The function which originates the information can be coded as a subscript to the i 's and q 's.

A matrix M_a can be constructed, showing the uses made of information items, if the functions are studied in sufficient detail to provide the necessary data. If M_a is compared with the availability matrix M_r , the usefulness of the information items can be analyzed.

M_a would appear:

	W_1	W_2	W_3	$\dots$	W_z
i_{11}	0	0	0		0
i_{22}	1	0	1		1
i_{13}	0	1	0		0
.					
.					
.					
i_{1w}	0	1	0		0
q_{11}	0	1	0		0
q_{12}	0	1	1		1
q_{13}	0	1	1		1
.					
.					
.					
q_{2y}	1	0	1		1

Still another matrix, M_d , can be constructed, in form similar to M_a but based upon the desired or optimum items of information that should be provided for each function, as determined by systems studies.

The value of these matrices does not lie in the fact that they show anything which could not be represented in other ways, e.g., by 300-foot rolls of paper or voluminous manuals. Rather, the value lies in the fact that the analyst has called upon mathematics for presentation of information in condensed and manipulable forms.

Not only does the model enable the analyst to picture the whole of a very complicated situation in a relatively simplified form, but the model offers other advantages. For example, because the relationships are delineated and grouped so precisely, it becomes relatively easy to divide the systems-study work among the members of an analysis group. Each can be given a different part of the study, with precise knowledge as to how their part fits into the whole picture.

Equally important, because the items are defined clearly and their flows established, it becomes much easier to provide the electronics

engineers with the volume, quality, and routing specifications which are so hard to obtain for present data-processing systems. It is in this direction that improvement in special electronic systems can most profitably be sought.

Another advantage is the experimentation which can be carried on with the model, to determine the effects of certain suggested system changes, without disturbing the actual system. This is a scientific advantage which is almost impossible to obtain, using present methods. In present systems, the direct effects of a systems change can usually be foreseen, but the second- and third-order effects, together with overlaps and other difficulties, are almost impossible to determine in advance. Indeed, they frequently go unrecognized even after the system change is put into effect. Efficiency suffers, but the cause is not ascertained.

Comparison of information transferred by the informal system, and that by the formal net, will give a new picture of the communication process. It will be possible to decide the extent to which the informal net should be encouraged, the amount of data which should be repeated over the formal net for verification purposes, and so on.

There are many other advantages afforded by the use of this type of model. However, the last we shall mention here is the important opportunity which is offered the analyst to incorporate into his system the advances which are taking place in programming, scheduling, and feedback, both conceptually and in terms of electronic equipment.

Uses of the Mathematical Model. There is a very fair chance that at this point the nonmathematical reader will say, "The matrices described above don't mean much to me. I don't see how I could use them in my own company."

The best answer is that it is not difficult to experiment with this type of model, applying it to real problems on a fairly small scale. The feasibility of such an approach can be tested by having someone in the systems and procedures department prepare only part of the model, e.g., matrix M_0 . For example, in a production firm the matrix M_0 could be prepared for the production orders.

In one case the matrix M_0 was prepared solely for labor source documents. The source documents used in this study were as follows:

1. Daily time card.
2. Daily labor-realization card.
3. Labor report required by the foreman from each individual.

After the *i*'s and *q*'s were listed for each of the source documents, it was evident that the *i*'s on the labor source forms made up two-thirds of the information gathered and the *q*'s were only one-third. In other words, it was evident, contrary to the executive's original impressions, that the amount of quantitative data gathered was much less than the amount of identification data.

Next, an examination of the *i*'s disclosed that there was a great deal of duplication in the identification data. For example, the production order code contained information as to date, account number, and lot number. The accounting codes also contained the account number and the lot number, although the order of the digits was different than for production control.

The matrix M_0 also made it quite clear that the daily labor-realization card duplicated data on the daily timecard. The duplication existed because the production department computed daily labor realizations, and the timekeeper needed the daily labor timecards to summarize the data for the weekly timecard. Later he sent the weekly card to centralized tab for payroll computation and for cost-accounting purposes as well as for reporting labor back to the foreman and to the other levels of management. The foreman's daily source forms duplicated the data on the other two forms except that it added one new piece of information. The latter dealt with the particular machine used by an individual worker during the production day.

Upon analysis it was determined that development of an integrated code, one which would designate organization, contract, and part number, would permit the dropping of about one-third of the digits currently used in the *i*'s.

Counting of the digits required for each of the *i*'s and *q*'s enabled the analyst to determine the volume of data needed for labor information, both currently and in storage. The amount of clerical labor, etc., necessary to compute the various source documents was easily determinable. In this particular case it was discovered that the timekeeper could be used for preparing the reports used by the foreman, which saved about four hours of his time as well as released two filing cabinets used to store the daily forms. The timekeeper also sorted the daily timecards as he checked them, so that when they reached the labor-realization clerks the first sorting was accomplished. Savings in paper costs were also realized, as one card was designed to serve for all three purposes.

Future Developments. The preceding section showed how mathematical "model" building could be used to determine how a business firm's present data system could be integrated, and how duplications, unused data, etc., could be eliminated. As indicated earlier, this is but the first step in the study of integrated data systems. The next major step will be integration of the data for reports and other types of communication in the feedback concept for programming and scheduling.

This programming and scheduling concept determines how, when, and what to produce, or what service to provide that would ultimately result in maximizing the use of the resources of the firm. The feedback to the original program and schedule is important to system integration. It is not uncommon to find many companies in which programs or schedules have been established, but no provision made for follow-up. In other cases the follow-up is so slow that no effective action can be taken. The report matrix for programming would differ from that used in the business processing system, in that it would provide for a more detailed examination of the user who reviews the report in a given function W . The reason for this is that in a business firm, as in other organizations, the decisions are made by various groups of persons, but the profitability of the firm depends on the joint result of all decisions. Furthermore, the profitability of the firm will depend not only on the various groups' decisions but also on external situations not under their control.

The model would also need to show the extent to which various organizational groups knew about the external situation as well as the internal situation, and what they need to know in order to make good decisions. In addition, the model should provide for the inclusion of local information and special data available to each group.

Models would have to be available for various types of decisions involving production, sales, and finance. These models could be viewed as fixed models, used to determine the optimal program or schedule. The information required to check the variables in these models could be determined. In addition, a requirement showing how often these variables should be provided could be built into the model. The accuracy requirement of the variables could also be determinable from the model.

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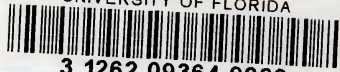
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